ENERGY 2020 Documentation

Volume 7

Policy Analysis

Last Revision: June 2017

www.ENERGY 2020.com

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Policy Analysis using ENERGY 2020

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1. Introduction

1.1. Policy Analysis Capabilities

ENERGY 2020 is a powerful analysis tool for simulating a wide variety of policies which impact the energy system across energy demand, energy supply, and emissions. Policies are designed to test impacts of changes made to the energy system in relation to a business-as-usual, or reference case, scenario. Examples of policies include building codes, efficiency standards and regulations, energy efficiency programs, incentives promoting fuel switching, addition or retirement of specific types of electric generating capacity (such as coal, nuclear, wind, solar), taxes on greenhouse gas emissions, and cap-and-trade programs.

Figure 1 provides a sample of the types of policies ENERGY 2020 is able to simulate across each of the residential, commercial, industrial, and transportation demand sectors, electricity, oil, gas, biofuels, refineries, and coal supply sectors as well as emissions-related policies crossing both demand and supply sectors.

Figure 1. Sample Policy Capability within ENERGY 2020 by Sector

Residential/Commercial

- Building and appliance efficiency standards
- Tax incentives
- Retrofit programs

Industrial

-Equipment efficiency standards

-Tax incentives and grant programs

Transportation

-Vehicle efficiency standards

-Alternative fuels

-Electric vehicles

Electric Supply

- Renewable generating capacity
- Interprovincial hydro transmission expansion
- Emission standards

Oil, Gas, Biofuel, Refineries, Coal Supply

- Enhanced production efficiency
- Sequestration of CO2
- Emission reducing technologies

Emissions

- GHG taxes
- Cap-and-trade programs
- CAC caps and reduction curves

1.2. Advantages of using ENERGY 2020 for Policy Analysis

Policies are intended to influence how energy consumers or producers make decisions. Because ENERGY 2020 is a behavioral model, simulating the decision-making process of consumers and producers, it incorporates policies into the simulation at the same point where actual decisions would be made. For example, a policy such as a new residential building code is built explicitly into model equations determining efficiency levels (which is logically where actual decisions about the efficiency levels of new homes being built are made).

ENERGY 2020 simulates the energy and emission system in significant detail; therefore, policies are able to be simulated to the specific level of detail defined in actual policies (such as to specific regions, industries, end uses, technology, fuels, generating units, and pollutants). Without a detailed representation, simulating detailed policies would require scaling policy parameters up to an aggregated level. As an example, ENERGY 2020 is able to simulate the details of a policy specifically applied to heavy fuel oil cogeneration in Alberta's fertilizer industry rather than requiring a scaled version of the policy applied to the entire chemical sector in Canada.

ENERGY 2020 executes on an annual basis allowing analysts to examine impacts for each year of the policy. Policy makers often are interested in the annual pattern of policy impacts in addition to its long term impact. For instance, the variability of a cap-and-trade price may be as significant an impact as the price in the final year. Another example would be in the development of renewable resources. Rapid development leads to higher emission reductions long term, but policy makers must determine if the rapid development is affordable and reasonable. Annual results allow users to review short term results and modify the policy if needed.

1.3. Organization of this Document

Volume 7 Policy Analysis provides guidance for creating commonly implemented energy policies using ENERGY 2020, including identification of key policy variables and explanations of the methodology behind policy impacts. The types of policies covered in this document focus on demand sector and electric supply sector policies. An overview of some key model structures used to simulate more complicated emissions policies, such as carbon taxes and cap-and-trade policies, also are provided. This document is divided into the six sections listed below.

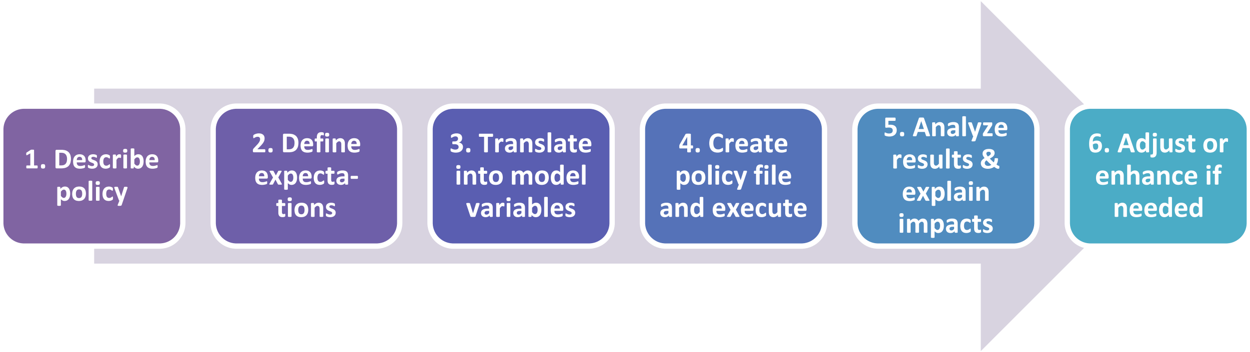
Section 1. Introduction
Section 2. Creating Policy Simulations
Section 3. Methodology for Common Demand Sector Policies
Section 4. Methodology for Common Electric Supply Sector Policies
Section 5. Methodology for Common Emissions-Related Policies
Section 6. Summary of Key Policy Variables

2. Creating Policy Simulations in ENERGY 2020

2.1. Process of Analyzing Policies

The process of creating policies in ENERGY 2020 begins with describing the policy in detail, defining expectations of policy impacts, translating the policy into model variables, creating an ENERGY 2020 policy file and executing the model, then analyzing and explaining model results to determine whether any adjustments to the policy is required. The steps involved in creating a policy simulation in ENERGY 2020 are summarized in Figure 2 and described in further detail below.

Figure 2. Steps to Creating a Policy Simulation in ENERGY 2020



When doing policy analysis in ENERGY 2020, the first step is to describe and define the actual policy in detail (Step 1), including specifics such as the specific industries, geographic areas, fuels, end uses, years, and types of processes which are to be covered by the policy as well as associated costs. Once the policy is clearly defined, the next step is to consider what impacts you expect to see from the policy – both direct impacts and indirect (Step 2). For example, if you are planning a simulation of a residential lighting policy in Alberta, a direct impact you might expect would be a decrease in Alberta's residential electricity demand for lighting. An indirect impact might be a decrease in electric generation due to decreased lighting demand and potentially a decrease in electricity prices. Identifying these expectations will help determine what to look for in model results and assess the reasonableness of those model results.

After identifying the expected impacts of the policy, you are ready to translate the policy into changes to ENERGY 2020 model variables by creating a policy file then to execute ENERGY 2020 (Steps 3 and 4). Policy files are described further in Section 2.2.

When reviewing model results (Step 5), determine the impacts of the policy by calculating the difference between results from the policy case and the business-as-usual case. Any impacts that differ from expectations point to areas that require further investigation and explanations in terms of model relationships. Often when reviewing results, you will identify an area which needs further specification or may have been missed during policy definition. Review and enhance the policy definitions or policy file as required and repeat the process until no further modifications are required (Step 6).

2.2. Policy Files to Modify Model Variables

Policy files in ENERGY 2020 are written as text files that contain code written in Promula language and, by convention, are saved with a ".txp". They modify values of input or policy variables used in key ENERGY 2020 model equations. Policy files are executed in ENERGY 2020 using batch files. A batch file is a separate file, with a ".bat" extension, consisting of a set of operating system commands to execute the model. Each policy is represented as its own policy file or set of policy files. Multiple policies can be combined by creating multiple policy files and executed together to define a scenario.

What are Policy files?

- Text files that contain code written in Promula language.
- Saved with a *.txp .extension ("policy text file")
- Modify values of input variables.
- May execute multiple policy files together to define a scenario.
- Are executed through ENERGY 2020 using batch files.

Existing Policy Files

The easiest method of creating a new policy file is to modify the values within an already existing policy file. Values can be specified by direct input, an equation, or a set of equations. Equations allow the values to be specified as a fraction of an existing model variable, including a percent change from a base case or reference case. Setting values of a policy variable in relation an existing model variable greatly facilitates and improves the accuracy of the representation of complex policies.

To simulate the impact of single policy in the forecast, a policy file is developed that makes changes to all the relevant model variables. An appropriate base line or reference scenario is identified and a new model run is executed with the new policy added on top of the forecast that it is being compared to. The impact of the policy is the difference in the model results between the two cases. A portfolio of policies can be individually tested then added together to develop entire forecast scenarios.

See *Appendix 1. List of Existing Policy Files in ENERGY 2020* for file names of existing policies located in ENERGY 2020's 2020Model subdirectory (developed as part of the 2016 reference case forecast for Canada).

New Policy Files

To translate a policy into model variables and equations requires an understanding of the model structure and may require assistance. ENERGY 2020 has been designed to be flexible and to facilitate the addition of new polices; however, often times a policy is new and unique and requires revisions to the model (for example, adding a new policy variable into model equations that simulate the energy consumers' or suppliers' decision making process). Revising the model variables or structure generally requires assistance from Systematic Solutions, Inc. (SSI). Recent examples where SSI revised model code to incorporate a new policy include: 1) creating the ability to allow for differences between various cap-and-trade proposals; and 2) restructuring the electric generation module as part of simulating the Alberta Clean Air Strategic Alliance (CASA) program to retire units when the cost of emission reduction retrofits are expected to exceed revenues

The sections that follow identify the primary ENERGY 2020 model variables to modify as well as the model methodology used to simulate a set of common demand-sector, electricity supply sector, and emissions-related policies.

3. Methodology for Common Demand Sector Policies

Demand sector policies are applied to one or more of the residential, commercial, industrial, and transportation sectors. They are typically designed to reduce energy consumption or emissions through changing usage patterns, increasing energy efficiency (through codes, standards, programs or incentives), or promoting cleaner fuel choices. Specific examples include building codes, vehicle efficiency standards, energy efficiency programs that promote compact fluorescent lighting, incentives for fuel switching to geothermal heating systems or solar panels, and many more. Demand sector policies commonly fall into one of four categories as described below.

3.1. Four Types of Demand Sector Policies

Within ENERGY 2020, demand sector policies fall into four broad categories which are based on the model structures directly impacted by the policy. These four types of policies are those that impact: 1) fuel choice, 2) process efficiency, 3) device efficiency, and/or 4) stock levels. Determining which of these four categories a policy falls into will help you to identify which model variables to use when simulating demand sector policies.

When simulating demand sector policies in ENERGY 2020 identify which model structure the policy will directly impact:

1. ***Fuel choice***
2. ***Process energy efficiency***
3. ***Device energy efficiency***
4. ***Stock levels***

Fuel choice: Marginal fuel market shares of new consumer purchases (distinguished from replacements) are calculated using principles from consumer choice theory. The marginal fuel market share represents the proportion of specific fuels chosen (such as 50% electric, 25% natural gas, 25% oil) for a specific type of purchase. For example, when there is growth in the residential sector, new housing construction creates a need for new space heating purchases. The model projects new residential space heating fuel market shares based on relative costs across fuel options as well as non-price factors.

Policies can be developed to modify the reference case mix of fuels chosen. These types of policies are often referred to fuel switching policies through promoting a specific choice of fuel (for example, promoting geothermal space heating, ethanol, biodiesel or electric vehicles, and encouraging the electrification of residential and commercial sectors). Note that, by default, the fuel market shares are calculated only for new additions to capital stock (rather than to replacements due to retirements caused by wear-out at the end of their useful lifetime). By default, retired stock are replaced with a similar type of technology (of the same fuel source). However, the model also has the capability, with the use of a switch, to allow consumers to convert to alternative technology types at the end of a physical lifetime.

Process energy efficiency: ENERGY 2020 distinguishes between process and device energy. Process energy refers to general forms of energy required by consumers, such as the amount of heating, cooling, lighting, or industrial processes energy required each year. Process energy represents the general type of energy requirement which is in contrast to device energy which represents the specific devices used to meet the total process energy requirements, such as furnaces, air conditioners, or light bulbs. The amount of process energy required by consumers is impacted by the efficiency of the systems requiring energy. For example, the process energy efficiency of residential heating system represents how much heating is required per unit of floor space. One of the factors influencing the process energy efficiency would be the efficiency of the building shell. Increasing insulation levels would decrease the amount of heating energy required per unit of floor space.

A marginal process energy efficiency is calculated in the model (during model initialization) using an efficiency-price response curve. Policies can be introduced to increase the business-as-usual level of process energy efficiency. Implementing a building code (which establishes a minimum building shell efficiency) is an example of a policy that would impact process efficiency. Other examples of policies that increase process efficiency include promotions encouraging consumers to reduce their vehicle distance traveled each year or obtaining commitments from industrial customers to use energy more efficiently in their industrial processes.

Device energy efficiency: In contrast to process energy, device energy represents the amount of energy consumed by devices, machines, or end uses, such as furnaces, light bulbs, and cars. The device energy efficiency is measured as the ratio of energy output per energy input for a specified device. For example, electric space heating energy efficiency is measured as the amount of heat output per energy used to create the heat. Device energy efficiency is calculated in the business-as-usual case based on principles of consumer choice theory combined with an efficiency-fuel price curve.

Policies can be introduced to modify the device energy efficiency levels of the business-as-usual case. Examples of policies that impact device energy efficiency include appliance/equipment standards that establish minimum device efficiencies for residential appliances, commercial and industrial equipment, and transportation vehicles. Other types of policies, such as energy efficiency programs, directly increase energy efficiency rather than setting a minimum standard. These energy efficiency programs encourage behaviors that increase energy efficiency as well as encourage purchases of energy efficient processes and devices.

Stock levels: ENERGY 2020 tracks vintaging (new, middle, and old) of three types of capital stock: 1) production capacity, 2) process energy, and 3) device energy. The production capacity represents by the sector's economic driver. For example, production capacity within the residential and commercial sectors is floor space, and within the industrial sector production capacity is gross output. The other two types of capital stock - process energy and device energy – were defined in the sections above.

Each year a portion of the capital stock is retired and replaced with new stock (based on the level of economic expansion). New capital stock is brought in at the most current efficiency levels (typically higher) and potentially with a different fuel choice. The remaining is aged by moving a portion into middle age and a portion into old age. With this vintaging process, new improved capital stock gradually replaces older capital stock over time, and the average efficiency of total stock takes multiple years to reflect newer higher levels of efficiency brought into the system. The rate at which capital stock is retired and replaced is determined primarily by the physical lifetimes of the capital stock.

Policies that impact the rate of retirement or addition of new capital stock fall into this stock level category. These policies typically are simulated by changing the lifetime of the capital stock (production capacity, process energy, or device energy). If the lifetime is reduced, then the old stock will be replaced more quickly with new capital stock. Policies may include incentives which promote a faster turnover of the existing stock in the model resulting in quicker program benefits.

Retrofit programs are examples of programs which could be thought of as retirement and replacement of capital stock. Alternatively, retrofit programs can be simulated in a more complex way using consumer choice theory to simulate consumers' decisions about retrofitting. Either of these methods is able to be used to simulate retrofit programs within ENERGY 2020.

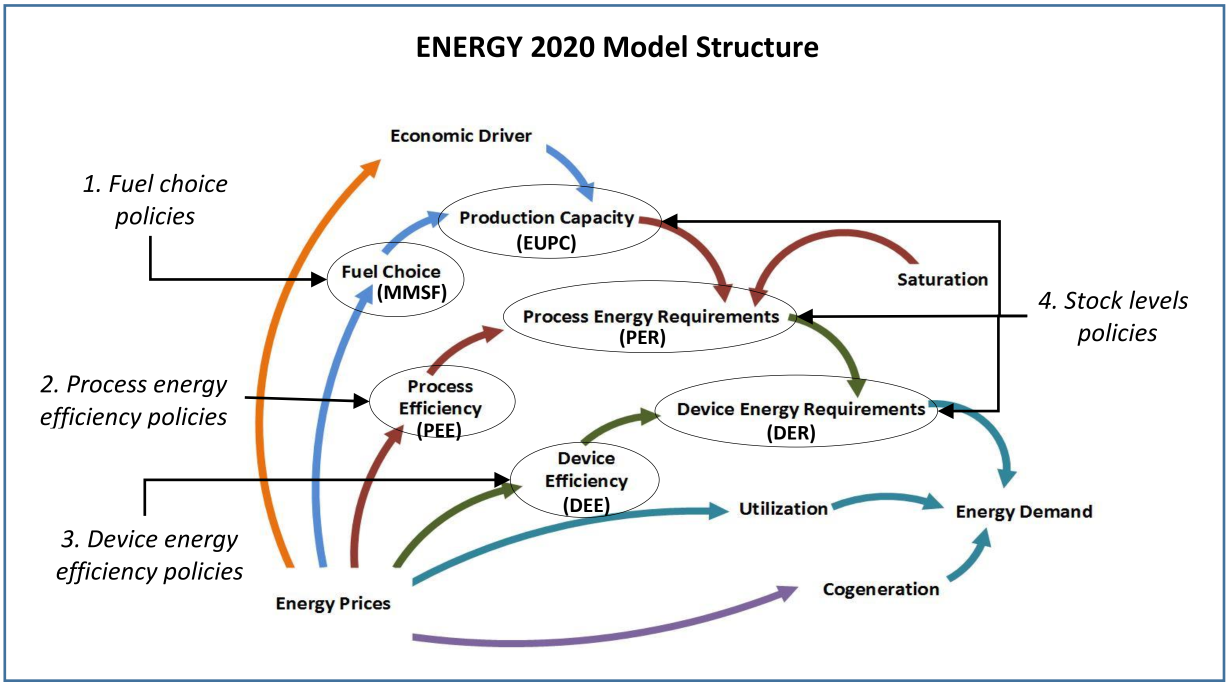
The following section links these four categories of demand sector policies (fuel choice, process energy efficiency, device energy efficiency, and stock levels) to the demand sector structural relationships built into ENERGY 2020.

3.2. Demand Sector Model Relationships

The model structures impacted by the most common demand sector types of policies (fuel choice, process energy efficiency, device energy efficiency, and stock levels) are circled in Figure 3. This figure illustrates the key relationships defined in the demand sector (see *Volume 3 Demand Sector Code* for more detailed description*)*. The circled structures point to the location of key equations impacted when implementing the demand sector policies. The names of the primary variables calculated within each structure is identified in parentheses.

Policies designed to impact consumer fuel choices or fuel switching are implemented within the model's fuel marginal market share fraction (MMSF) equation. Process and device energy efficiency policies are implemented within the model equations calculating process and device energy efficiency (PEE, DEE). Finally, policies impacting the rate of change, retirements, or additions in the levels of capital stock (production capacity, process energy, or device energy) are implemented into the equations calculating production capacity (EUPC), process energy requirements (PER), and device energy requirements (DER).

Figure 3. Demand Sector Policy Linkage to ENERGY 2020 Model Structure

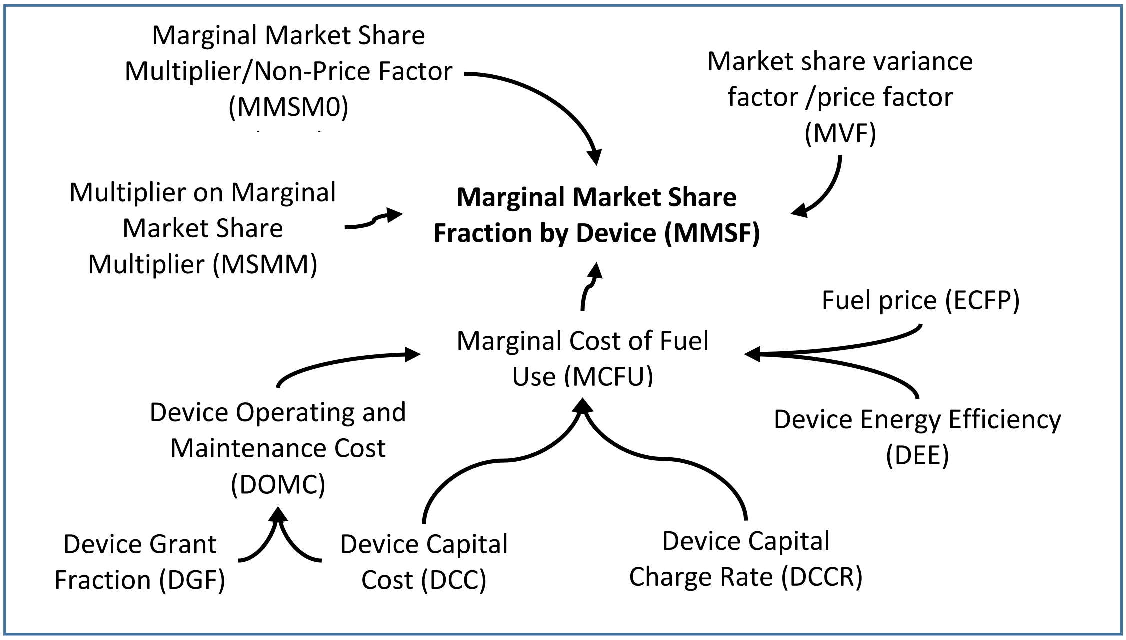


3.3. Fuel Choice Policies (Fuel Switching)

Policies designed to modify the fuel mix are aimed at shifting the marginal market share fraction (MMSF) of a particular fuel by device. Consumers choose alternative fuels as the relative costs of each option change or as non-price factors change (such as perceptions of products that could shift due to marketing efforts).

Figure 4 graphically shows inputs to the fuel choice marginal market share (MMSF) equation. A marginal market share fraction is calculated across fuels for each end use (device) represented in the model. The key inputs to the equation are: marginal cost of fuel use (MCFU), fuel price variance factor (MVF), a marginal market share multiplier/non-price factor (MMSM0), and multiplier on the marginal market share multiplier (MSMM). The key inputs to the marginal cost of fuel use (MCFU) are also shown on the figure consisting of: fuel price (ECFP), device energy efficiency (DEE), device capital cost (DCC), device capital charge rate (DCCR), device operating and maintenance costs (DOMC), and a device grant fraction (DGF) which is a policy variable impacting the operating and maintenance costs.

Figure 4. Marginal Market Share Equation Inputs



Changes to any of the variables shown in the figure above will impact the marginal market share fraction of fuels. Shifts in fuel shares will occur from shifts in the relative price of fuels (changes in capital costs, efficiency, or fuel prices). Additionally, shifts in fuel shares will occur due to changes in consumers' non-price factors (propensity toward or resistance to particular fuels). Whereas changes to the values of any of the market share equation input variables will impact the fuel market shares, the variables most commonly used to simulate a fuel switching policy are listed in Table 1.

Table 1. Policy Variables for Fuel Choice Policies

Variable Name	Description
Fuel choice market share (shift consumers' non-price perceptions)	
$MMSM0_{(Enduse,Tech,EC,Area,Year)}$	Marginal Market Share Multiplier/ Non-Price Factor ($/$). This variable represents the non-price propensity toward or barrier to a specified technology (end use-fuel combination). It is endogenously calculated during the historical calibration and assigned future values to set the marginal equal to the average. Modifying the value of MMSM0 overwrites the endogenously-calculated value assigned during calibration and can be used to promote specific technologies compared to the reference case.
$MSMM_{(Enduse,Tech,EC,Area,Year)}$	Multiplier on Marginal Market share Multiplier ($/$). This variable is used as an adjustment multiplier on the marginal market share. Setting a value for this variable can promote specific technologies without directly changing the value of the calculated non-price factor, MMSM0. The default value for this multiplier is 1.0.
Fuel choice (shift relative price of fuels)	
$DGF_{(Enduse,Tech,EC,Area,Year)}$	Domestic Grant Fraction ($/$). The DGF variable is an input to the marginal cost of fuel usage calculation. It is used as a policy variable to assign rebates and price incentives as a means to shifting the market share. Its default value is set to 1.0.
Fuel choice (set an exogenous value fuel market share fraction)	
$XMMSF_{(Enduse,Tech,EC,Area,Year)}$	Exogenous Marginal Market Share Fraction by Device ($/$). If the expected market share needs to be set to a specified value, such as to match an exogenous forecast, an exogenously-specified marginal market share can be assigned.

Expected Fuel Share Policy Impacts

Identifying the expected impact of a policy will help in analyzing the results of a model run to determine whether a policy was specified properly. For a fuel switching policy, the expected impact would include a direct impact of increased energy demand for the fuel type promoted and decreased energy demand for other fuels. Indirect impacts may include changes to generation and production levels from the supply sector, electricity prices, energy expenditures, and emissions.

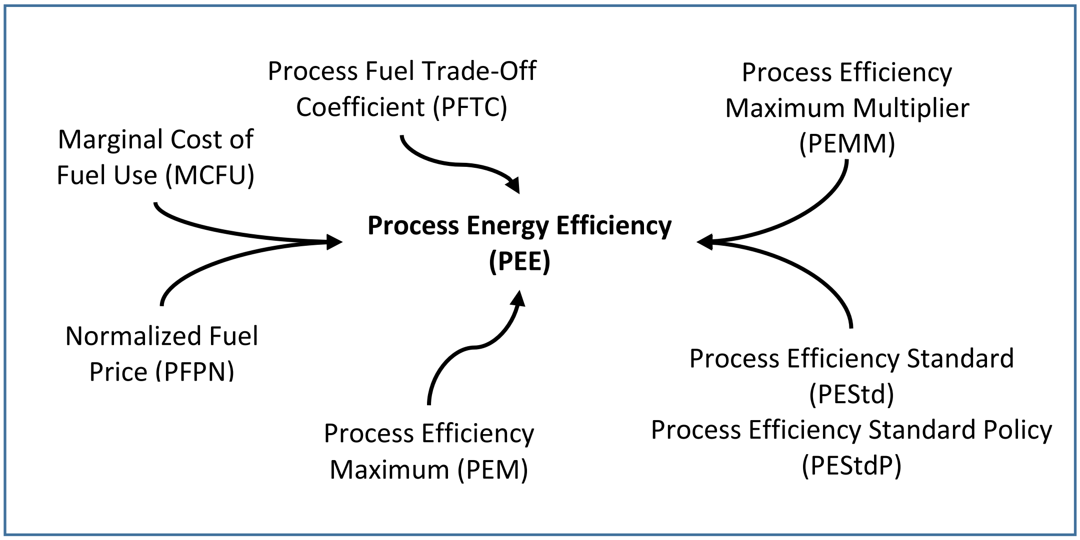
Example of Existing Fuel Share Policy

Appendix 1 lists existing policy files created for the 2016 reference case. An example of an existing ENERGY 2020 policy file that demonstrates an electric vehicle fuel switching policy within Quebec's transportation sector is named *Trans_EV_QC.txp* and resides in ENERGY 2020's 2020Model subdirectory.

3.4. Process Energy Efficiency Policies

Process energy efficiency policies, such as building codes, are simulated as part of the model's marginal process energy efficiency (PEE) equation. ENERGY 2020 forecasts efficiency of new process energy using price response curves to simulate the trade-off between cost and efficiency. Components of the price response curve equation are shown in Figure 5 and include the following inputs: marginal cost of energy (MCFU), process efficiency trade-off curve coefficient (PFTC), normalized fuel price (PFPN), process efficiency maximum (PEM), process efficiency maximum multiplier (PEMM), existing process efficiency standards (PEStd), and a variable designated to represent efficiency standards policies (PEStdP).

Figure 5. Process Energy Efficiency Inputs



The process efficiency standard (PEStd, PEStdP) sets a minimum on marginal energy efficiency (PEE) – PEE is assigned to be the maximum of the calculated process efficiency and any process efficiency standards (either existing or policy-related). The process efficiency maximum (PEM) represents the maximum efficiency level, and the process efficiency curve asymptotes to the maximum. The curve is able to be modified up or down by adjusting the maximum using the process efficiency maximum multiplier (PEMM).

Two methods are commonly used to simulate process energy efficiency policies:

1) Set a minimum value for the process efficiency using a process efficiency standard (PEStdP); and/or
2) Adjust the process efficiency curves upward or downward, using the process efficiency maximum multiplier (PEMM), such that for a given fuel price, higher efficiency levels are chosen.

Process energy is assigned both an energy efficiency and an associated capital cost. The efficiency and capital cost variables are linked in that a capital cost is assigned based on the efficiency level chosen. Therefore, any changes to process energy efficiency will impact capital cost.

To determine process energy capital costs, ENERGY 2020 uses a capital cost trade off curve coefficient (PCTC), developed during model initialization and held constant through the model run, combined with the level of process energy efficiency and a set of multipliers, all subject to a maximum efficiency. Adjustments to the curve can be made using the process capital cost maximum multiplier (PCCMM). Figure 6 identifies the inputs to the process energy capital cost equation.

Process Energy Capital Costs
When simulating a process energy efficiency policy, the resulting capital costs should be examined. With an increase in energy efficiency, the capital costs increase based on a curve developed from historical relationships calculated during model initialization. As part of the policy simulation, you may want to adjust the capital cost curve up or down to reflect current thinking as to the relationship of cost and efficiency levels.

Figure 6. Process Energy Capital Cost Inputs

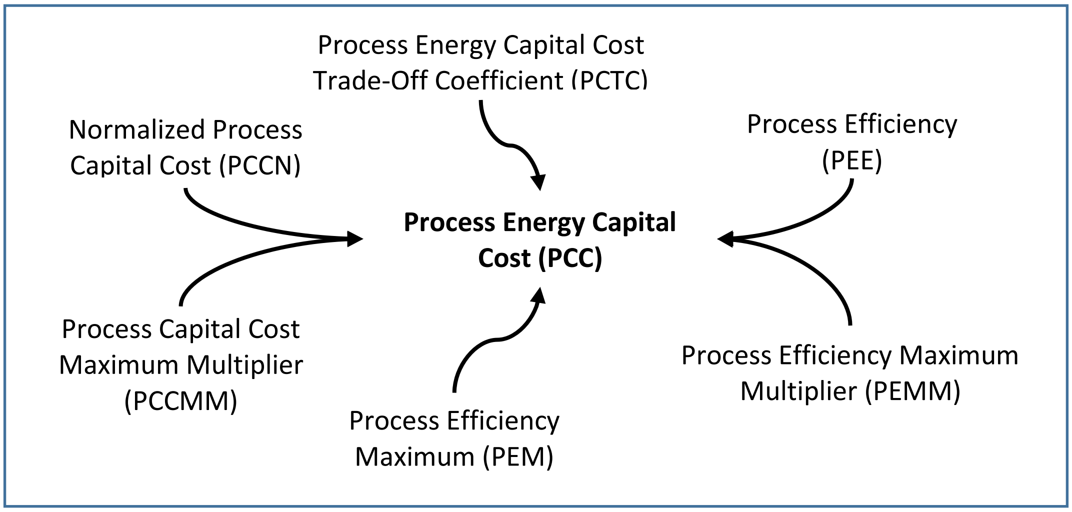


Table 2 summarizes the variables most commonly used to simulate process efficiency policy.

Table 2. Policy Variables for Process Energy Efficiency Policies

Process Energy Efficiency Policy Variables	
Variable Name	**Description**
$PEStdP_{(Enduse,Tech,EC,Area,Year)}$	Process Efficiency Standard Policy ($/Btu or M^2/Btu). Assign a process efficiency standard policy which establishes the minimum level of process efficiency chosen by the model. This method can be used when the actual planned level of efficiency is known or if the user wants increases in efficiency to increase capital costs via the efficiency curves. For example, a standard can be applied to simulate a building code policy that expects to increase construction costs.
$PEMM_{(Enduse,Tech,EC,Area,Year)}$	Process Efficiency Maximum Multiplier ($/Btu/$/Btu). Adjusting the process efficiency maximum multiplier (PEMM) modifies the efficiency curve by increasing its maximum level and results in an increase in the marginal efficiency selected at each fuel price.
$PCCMM_{(Enduse,Tech,EC,Area,Year)}$	Process Efficiency Capital Cost Maximum Multiplier ($/Btu/$/Btu). Adjustments to the capital cost multiplier (PCCMM) allows the user to adjust the capital cost curve produced by the model upward or downward. For a given level of efficiency, the capital cost will be increased or decreased based on the multiplier.

Expected Process Efficiency Policy Impacts

The expected impacts of these process efficiency policies include the following:

- Direct impacts: Increase to process efficiency for residential, commercial, and/or industrial sectors; Cost curve modified to increase expected capital costs.
- Indirect impacts: Reduction in energy use and emissions; changes to expenditures; reduction in electric generation (from reduced enduse demand).

Existing Process Efficiency Policy Files

Existing policy files (taken from the 2016 reference case for Canada) that demonstrate process efficiency improvements are listed below and reside in ENERGY 2020's 2020Model subdirectory.

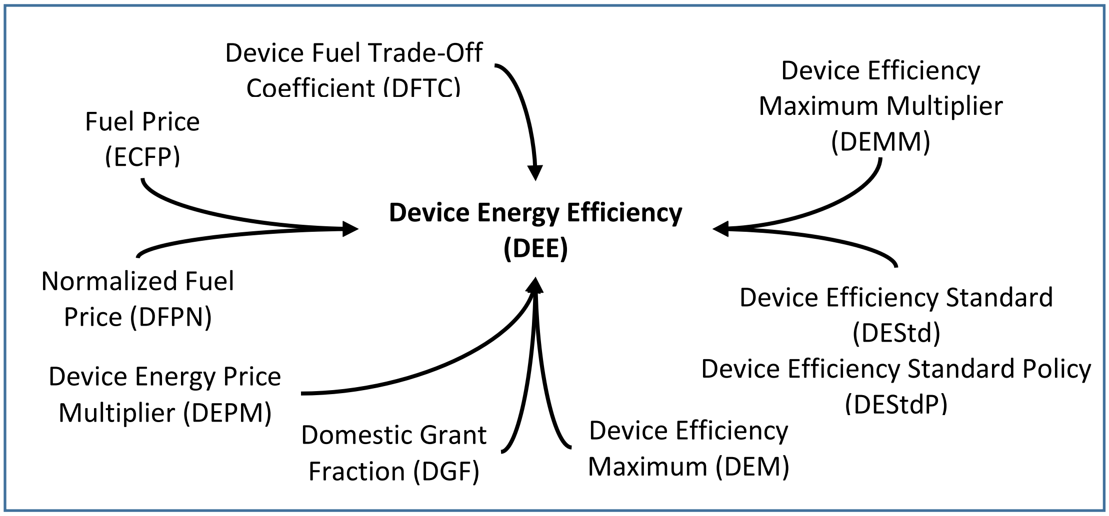
- *Buildings_CA.txp*: California Energy Efficiency Program.
- *Com_BldgStdPolicy.txp*: Commercial building code changes.
- *EcoEff_IdPr.txp*: Simulates PJ impacts from energy efficiency.
- *RT_Ind_Process.txp*: Increases the energy efficiency standard for industry processes in the industrial sector.

3.5. Device Energy Efficiency Policies

Establishing appliance/equipment efficiency standards and promoting appliance/equipment energy efficiency programs are examples of device energy efficiency policies. Equipment standards establish minimum device energy efficiencies for residential appliances, commercial and industrial equipment, and transportation vehicles. Each type of appliance, such as furnaces, could have a different efficiency standard for each fuel type. Policies that simulate energy efficiency programs are designed to encourage consumers to reduce energy consumption, such as programs to promote purchasing energy efficient light bulbs.

The principles of increasing device efficiency mimic those of increasing process efficiency. Figure 7 illustrates the variables that are used to calculate device energy efficiency. The device efficiency of a specific enduse and fuel is determined using a device efficiency fuel trade-off curve. The coefficient that defines the trade-off curve, DFTC, is developed during model initialization and held constant through the model run. Marginal device efficiency (DEE) is determined by the relative energy price (ECFP, DFPN) and the device efficiency curve parameters (DEM, DFTC). The device efficiency multiplier (DEMM), the domestic grant fraction (DGF) and the device price multiplier (DEPM) are policy variables. The ultimate device energy efficiency (DEE) is assigned the maximum of the calculated device efficiency and any device efficiency standards (either existing or policy-related).

Figure 7. Device Energy Efficiency Inputs



Other Factors to Consider

Other factors to consider when simulating policies that modify device energy efficiency are: 1) capital cost of the new energy efficient devices, and 2) lifetime of the new energy efficiency devices. The model equations related to device capital cost are described below. Modifying the device lifetime will impact the rate of retirements and new additions of device energy. Model equations related to device lifetime are described in *Section 3.6* related to policies impacting stock levels.

Device energy capital costs are calculated based on the level of device efficiency using a device capital trade off curve coefficient (DCTC), developed during model initialization and held constant through the model run, combined with cost and efficiency multipliers and subject to a maximum efficiency. Figure 8 identifies the inputs to the device capital cost equation.

Device Energy Capital Costs

When simulating a device energy efficiency policy, the resulting capital costs should be examined. With an increase in energy efficiency, the capital costs increase based on a curve developed from historical relationships calculated during model initialization. As part of the policy simulation, you may want to adjust the capital cost curve up or down to reflect current thinking as to the relationship of cost and efficiency levels.

Figure 8. Device Capital Cost Inputs

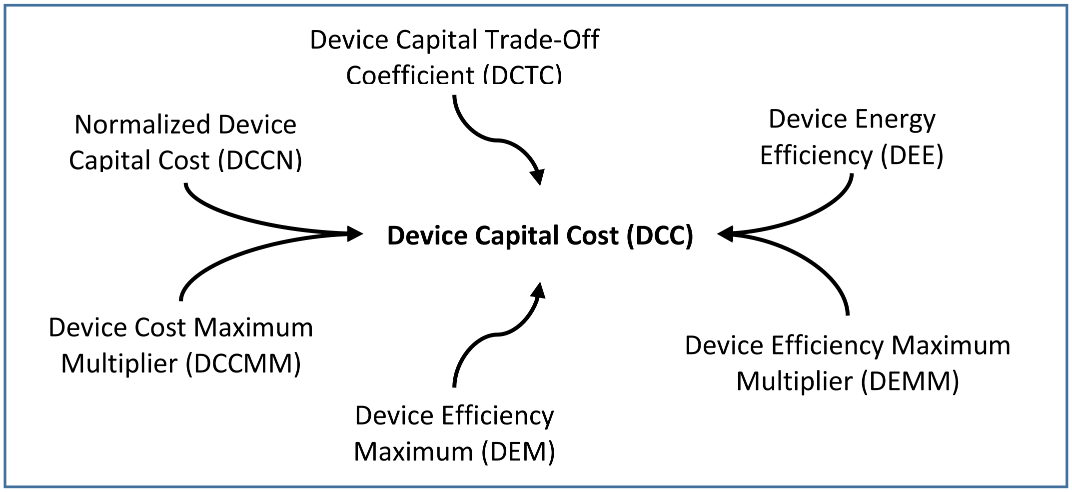


Table 3 lists the policy variables commonly used to simulate appliance/equipment efficiency standards and appliance energy efficiency programs. These policy variables can be applied to any of the residential, commercial, industrial, or transportation sectors.

Table 3. Policy Variables for Device Energy Efficiency Policies

Device Energy Efficiency Policy Variables	
Variable Name	**Description**
$DEStdP_{(Enduse,Tech,EC,Area,Year)}$	Device efficiency standard policy (Btu/Btu). Assign a device efficiency standard policy which establishes the minimum level of device efficiency chosen by the model. This option can be used when the level of desired efficiency is known and can be directly input. An efficiency standard can also be set to allow for the model to increase capital cost based on the efficiency curve parameters.
$DEMM_{(Enduse,Tech,EC,Area,Year)}$	Device Efficiency Maximum Multiplier (Btu/Btu). Adjusting the device efficiency maximum multiplier (DEMM) modifies the efficiency curve by increasing its maximum level and results in an increase in the marginal efficiency selected at each fuel price. Changing the efficiency maximum multiplier will produce a response in efficiency without a corresponding change in capital cost given the same level of fuel price.
$DCCMM_{(Enduse,Tech,EC,Area,Year)}$	Device Efficiency Capital Cost Maximum Multiplier (Btu/Btu). Adjustments to the capital cost multiplier (DCCMM) allows the user to adjust the capital cost curve produced by the model upward or downward. For a given level of efficiency, the capital cost will be increased or decreased based on the multiplier.
$DPL_{(Enduse,Tech,EC,Area,Year)}$	Physical life of devices (Years). With increased appliance energy efficiency, the lifetime of devices may need to be increased if appropriate, for example, CFL or LED lighting have longer lifetimes than incandescent. The physical lifetime of devices is used to calculate the retirement rate of the device. Policies that promote early scrappage of devices, such as vehicles, in favor of new efficient devices can be applied by adjusting the device physical lifetime variable.

Expected Device Efficiency Policy Impacts

The expected impacts of these process efficiency policies include the following:

- Direct impacts: Increase to specific device efficiencies; adjustments to device cost curve to match anticipated increases to capital costs by technology; quicker adoption of newer, more efficiency devices.
- Indirect impacts: Reduction in energy use and emissions; changes to expenditures; reduction in electric generation (from reduced enduse demand).

Existing Device Efficiency Policy Files

Existing policy files (developed as part of the 2016 reference case) that demonstrate device efficiency improvements are listed below and reside in ENERGY 2020's 2020Model subdirectory.

- *Ind_DeviceEff.txp*: This policy file simulates Quebec's EcoPerformace Program.
- *PavleyPhaseII_CA.txp*: California Pavley Phase II Vehicle Passenger Efficiency Program. *EnergyEfficiency_CA.txp*: California Energy Efficiency Program
- *Reference_US_Lighting_EMF.txp*: Lighting Program (Incandescent Phase-Out)

3.6. Stock Levels Policies

Policies that impact the rate of retirements or additions of any of the three types of capital stock in the model - 1) production capacity, 2) process energy, and 3) device energy – fall into the stock levels types of policies. These three types of capital stock are interrelated in that changes in the level of production capacity drive changes to process energy requirements, and the changes to process energy requirements drive changes to device energy requirements. ENERGY 2020 tracks old, middle, and new vintages of production capacity. As the old production capacity is retired and replaced or as new production capacity is added, new process and device energy is brought into the market at the marginal (new) levels of efficiency and capital cost.

> *ENERGY 2020 retires and/or adds capital stock (production capacity, process energy, and device energy) in the following situations:*
>
> - *Economic growth or decline*
> - *End of physical lifetime/wear-out*
> - *Retrofits and conversions*
> - *Exogenously specified device saturation levels*

Economic growth or decline: With economic growth or decline, new production capacity is added or existing production capacity is retired. For example, with economic or population growth, the number of single family homes will increase which increases the square footage that requiring energy (production capacity). The increased production capacity, in turn, increases the process energy requirements (heating for example) which increases the need for device energy (furnaces to provide the heat). ENERGY 2020 increases all three forms of capital stock (production capacity, process energy, and device energy) when there is economic growth and retires capital stock with economic decline.

End of physical lifetime/wear-out: Capital stock is retired and replaced at the end of its physical lifetime. For example, when a heater is old and fails, it is replaced with a new heater. As a default setting in the model, when devices are replaced, they are replaced with the same type of technology (old electric space heat is replaced with new electric space heat). Conversions to alternative technologies are able to be made by activating the conversion variables (described in the conversion sections below). Additionally, retirements and replacements are able to be made before the end of the capital stock physical lifetime by activating the retrofit variables in the model (described in the retrofits section below).

Retrofits and conversions: Retrofits allow the replacement of process or device energy before the end of the physical lifetime. Alternatives exist in the model to input exogenous levels of retrofits or to invoke endogenous levels based on consumer choice equations. Conversions allow the replacement of process or device energy of one specific technology type with alternative technology options at the end of the physical lifetime (for example allowing electric space heat to be replaced with options of natural gas, geothermal, or oil space heat). The fraction of conversions able to be exogenously input or endogenously calculated using consumer choice equations.

Exogenously-specified device saturation: Exogenous specification of device saturation levels may lead to direct additions or retirements of devices from the capital stock in order to match the specified saturations.

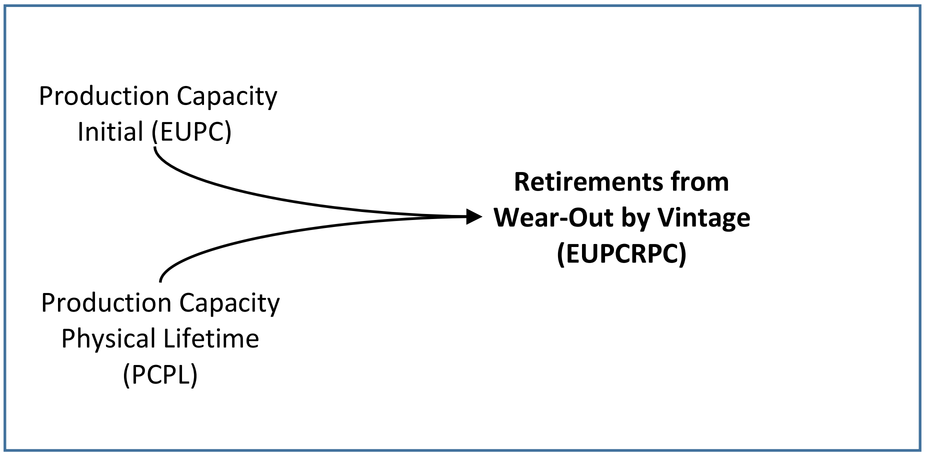
Policies that modify any of the above areas will impact the stock levels and mix of efficiencies and capital costs in the stock.

Retirements and Replacements due to End of Physical Lifetimes/Wear-Out

The retirements and replacements due to the end of physical lifetimes (or wear-out) of all three types of capital stock are interrelated. Modifying the physical lifetime of the capital stock will impact the rate of turnover of the stock. This section provides a brief overview of the model variables impacting the retirement and replaces due to wear-out of production capacity, process energy, and device energy.

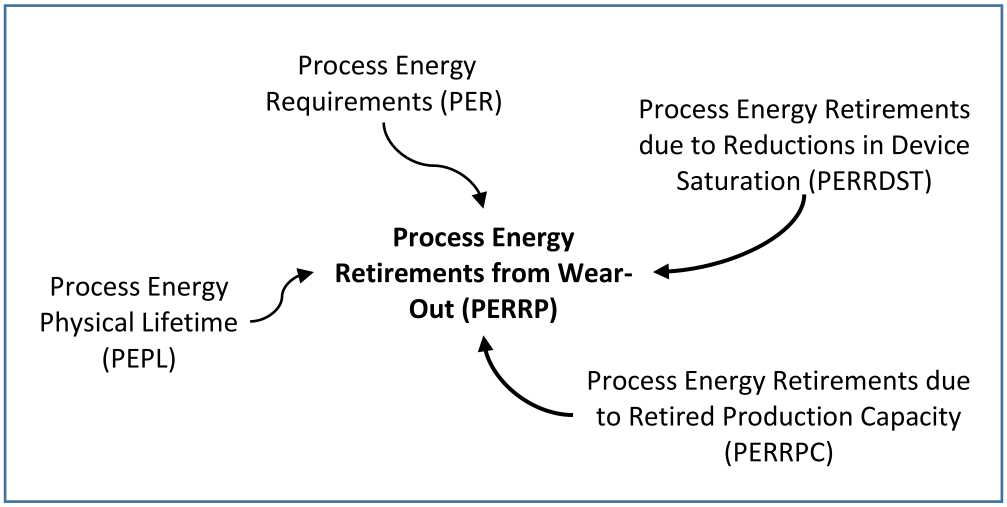
For production capacity retirements, the time spent in each vintage (new, middle, and old) is the production capacity lifetime (PCPL) divided by three since there are three vintages. The production capacity is retired when it leaves the third (old) vintage category. Figure 9 shows the model variables that impact retirements from wear-out of production capacity. The variables impacting retirements are production capacity by vintage and physical lifetime.

Figure 9. Variables Impacting Retirements from Wear-Out of Production Capacity



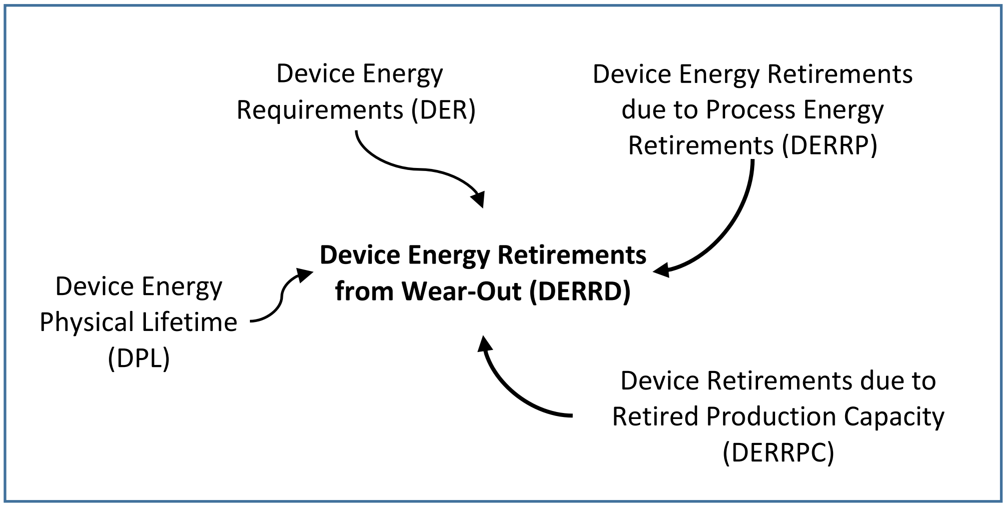
If production has been retired, both process energy and device energy also will be impacted. For process energy, retirements from wear-out are equal to process energy requirements (PER) less the process energy retirements due to production capacity retirements and reductions in the device saturation divided by the process lifetime (PEPL). Figure 10 shows the relationships of model variables impacting process energy from wear-out.

Figure 10. Variables Impacting Retirements from Wear-Out of Process Energy



Device energy retirements or failures (DERRD) are equal to device energy requirements (DER) less device retirements due to production capacity retirements (DERRPC) and device retirements due to process retirements (DERRP) divided by the average lifetime of the devices (DPL). Figure 11 shows the variables impacting the device energy retirements due to wear-out.

Figure 11. Variables Impacting Device Energy Retirements from Wear-Out



As long as process energy requirements exist, devices will be replaced. When a device wears out, the device is replaced since the process energy requirements still exist. New devices have the current marginal device efficiency (DEE), while the old device is assumed to have a device efficiency equal to the average device efficiency (DEEA).

Assuming no conversions, the additions from device wear-outs (DERAD) is equal to the device retirements (DERRD) times the ratio of average efficiency (DEEA) to marginal device efficiency (DEE). If the new marginal efficiency is the same as the old efficiency, then additions equal retirements. However, if new efficiency is higher than old efficiency, then we won't need to add as many devices due to the higher efficiency.

In summary, within all of these retirement scenarios, modifying any of the physical lifetimes will impact the rates of retirements and replacements and gradually the efficiency level of the overall stock. The impact of changing the physical lifetimes of any of production capacity, process energy, or device energy is summarized as follows:

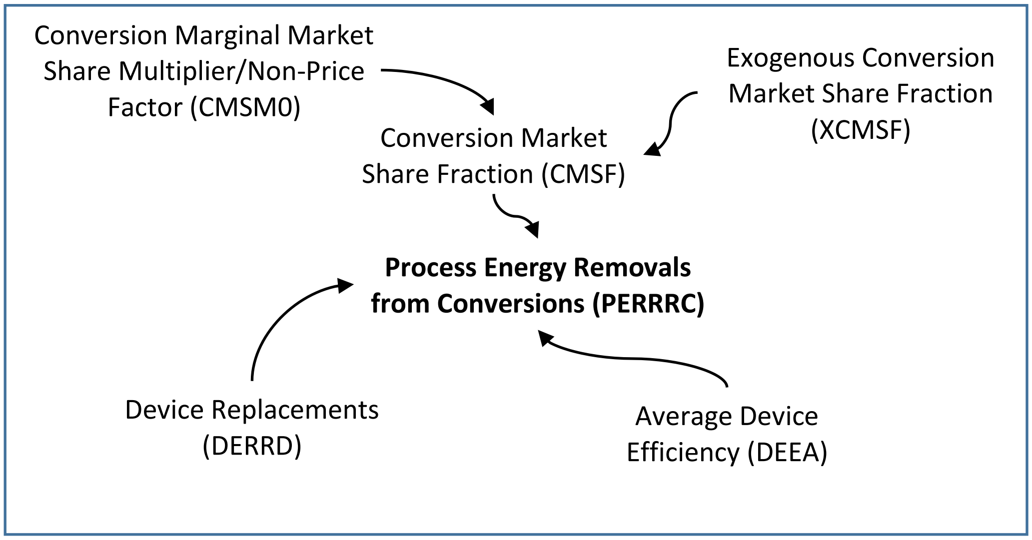
1. Changing the production capacity lifetime (PCPL) impacts production capacity retirements (which in turn impacts production capacity additions). This also impacts process energy and device energy additions and retirements.
2. Changing the process energy physical lifetimes (PEPL) impacts process energy retirements (which in turn impacts process energy additions). This also will end up impacting device energy retirements/additions.

3. Changing the device physical lifetimes impacts the device energy retirements (which in turn impacts device energy additions).

Retirements of Stock due to Conversions

If conversions are activated in the model, then at the end of the useful life of capital stock, new technology options are available to consumers (rather than forcing the replacement of the same type of technology). This switch activates the fuel market share equations and treats new additions from replacements the same as new additions due to economic growth. If the choice is made endogenously, then it is a function of the cost of the new technology (MCFU) less the "hurdle" cost (FDCC). These costs are "hurdle" costs in the sense that if change from electric baseboard heat to a gas furnace you must add duct work to the house. Variables required for the fuel market share equation of conversions are similar to the normal fuel market share equation. The process removals from conversions (PERRRC) are equal to the device replacements (DERRD) times the conversion market share (CMSF). The terms are multiplied times the average device efficiency (DEEA). Figure 12 illustrates the variables that impact process energy removals from conversions.

Figure 12. Variables Impacting Retirements from Conversions



Retirements of Stock due to Retrofits

With retrofits, we are removing capital stock before the end of its useful life. This could be done by shortening the physical lifetimes; however, the code that is specific to retrofits incorporates consumer choice decisions to determine the market share fraction of retrofits. The retrofits apply to both process energy and device energy. Figure 13 shows the variables impacting the removals of process energy from retrofits and XXX shows the variables impacting the device energy retrofits.

Figure 13. Variables Impacting Process Energy Removals from Retrofits

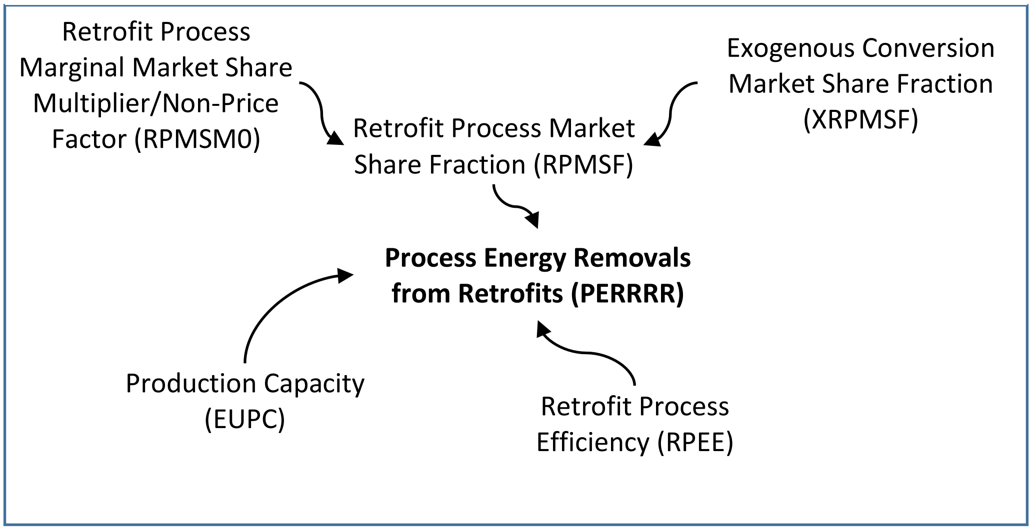


Figure 14. Variables Impacting Device Energy Removals from Retrofits

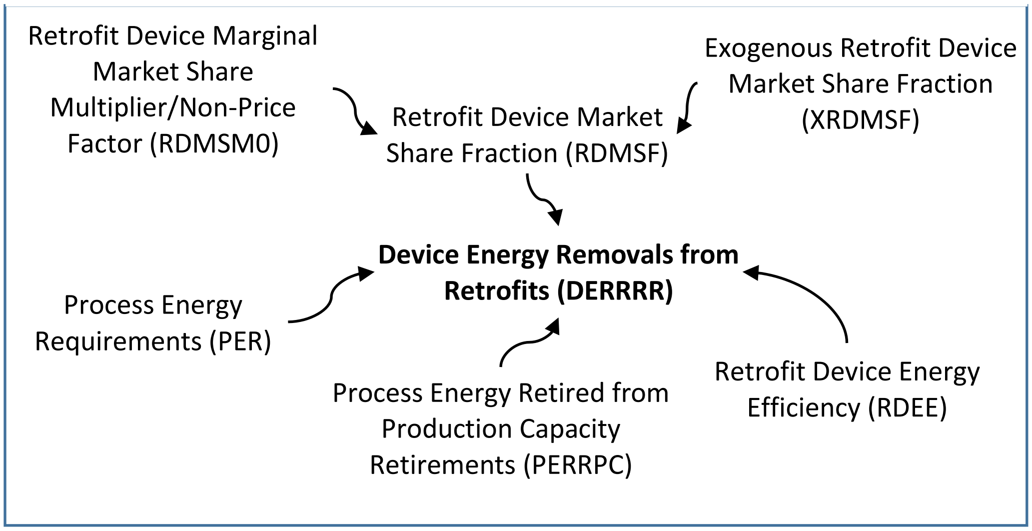


Table 4 summarizes the policy variables commonly used to simulate policies designed to impact the rates of change to the capital stock – either due to wear-out, conversions, or retrofits. These policy variables can be applied to any of the residential, commercial, industrial, or transportation sectors.

Table 4. Policy Variables for Stock Levels Policies

Stock Levels Policy Variables	
Variable Name	**Description**
Policy variables that modify physical lifetimes of capital stock (impacts rate that new capital stock is brought into market)	
$\text{PCPL}_{(\text{ECC,Area,Year})}$ $\text{PEPL}_{(\text{Enduse,Tech,EC,Area,Year})}$ $\text{DPL}_{(\text{Enduse,Tech,EC,Area,Year})}$	Physical Life of Production Capacity (Years). Physical Life of Process Energy Requirements (Years). Physical Life of Devices (Years). The physical lifetime variables are used to calculate the retirement rate of the capital stock (production capacity, process energy, or device energy). For quicker turnover of capital stock, physical lifetimes of any of the types of capital stock can be decreased. For example, policies that promote early scrappage of devices, such as vehicles, in favor of new efficient devices can be applied by adjusting the device physical lifetime variable.
Policy variables for retrofits (Replace capital stock before the end of the physical lifetimes using endogenous consumer choice or by setting exogenous level of retrofits)	
$\text{RPMSM0}_{(\text{Enduse,Tech,EC,Area,Year})}$	Retrofit Process Energy Marginal Market Share Multiplier/ Non-Price Factor (\$/\$). This variable represents the non-price propensity toward or barrier to a specified technology (end use-fuel combination). It is endogenously calculated during the historical calibration and assigned future values based on historical levels. Modifying the value of MMSM0 overwrites the endogenously-calculated value assigned during calibration and can be used to promote specific technologies compared to the business-as-usual case.
$\text{XRPMSF}_{(\text{Enduse,Tech,EC,Area,Year})}$	Exogenous Retrofit Process Energy Marginal Market Share Fraction by Device (\$/\$). If the expected market share needs to be set to a specified value, such as to match an exogenous forecast, an exogenously-specified marginal market share can be assigned.
$\text{RDMSM0}_{(\text{Enduse,Tech,EC,Area,Year})}$	Retrofit Device Energy Marginal Market Share Multiplier/ Non-Price Factor (\$/\$). This variable represents the non-price propensity toward or barrier to a specified technology (end use-fuel combination). It is endogenously calculated during the historical calibration and assigned future values based on historical levels. Modifying the value of MMSM0 overwrites the endogenously-calculated value assigned during calibration and can be used to promote specific technologies compared to the business-as-usual case.

Stock Levels Policy Variables	
Variable Name	**Description**
$XRDMSF_{(Enduse,Tech,EC,Area,Year)}$	Exogenous Retrofit Device Marginal Market Share Fraction by Device ($/$). If the expected market share needs to be set to a specified value, such as to match an exogenous forecast, an exogenously-specified marginal market share can be assigned.
Policy variables for conversions (allow conversions to alternative fuels at the end of device physical lifetimes using endogenous consumer choice equations or setting exogenous conversion fractions)	
$CMMSM0_{(Enduse,Tech,EC,Area,Year)}$	Conversion Marginal Market Share Multiplier/ Non-Price Factor ($/$). This variable represents the non-price propensity toward or barrier to a specified technology (end use-fuel combination). It is endogenously calculated during the historical calibration and assigned future values based on historical levels. Modifying the value of CMMSM0 overwrites the endogenously-calculated value assigned during calibration and can be used to promote specific technologies compared to the business-as-usual case.
$XCMSF_{(Enduse,Tech,EC,Area,Year)}$	Exogenous Conversion Marginal Market Share Fraction by Device ($/$). If the expected market share needs to be set to a specified value, such as to match an exogenous forecast, an exogenously-specified marginal market share can be assigned.

3.7. Summary Key Demand Sector Policy Variables

The most commonly-used policy variables in the demand sector are identified in Table 5 for all types of policies discussed in this section. These are applied to any of the residential, commercial, industrial, and/or transportation sectors. The policy variables listed in this table include those used for simulating fuel switching, increasing market penetrations, codes, standards, energy efficiency, incorporating estimates of demand-side management impacts, modifying rates of changes to capital stock, including retrofits and conversions.

Table 5. Demand Sector Common Policy Variables

No.	Policy Variable Name	Demand Sector Policy Variable Description
Fuel Switching and Market Penetration Policy Variables		
1.	MMSM0$_{(Enduse,Tech,EC,Area,Year)}$	Marginal market share multiplier constant ($/$). This variable is the non-price factor in qualitative consumer choice equation. Modify the value of MMSM0 to increase the propensity toward (or barriers to) a particular technology.
2.	MSMM$_{(Enduse,Tech,EC,Area,Year)}$	Non-Price Market Share Factor Multiplier (1/1). Assign a value to MSMM to adjust the non-price factor by a percentage value.
3.	DGF$_{(Enduse,Tech,EC,Area,Year)}$	Domestic Grant Fraction ($/$). Applies a rebate to the price and capital cost of devices, producing a shift in endogenous efficiency and capital costs .
4.	XMMSF$_{(Enduse,Tech,EC,Area,Year)}$	Exogenous market share fraction ($/$). Some policies presume an expected market share.
Codes, Standards and Energy Efficiency (Process and Device)		
5.	PEStdP$_{(Enduse,Tech,EC,Area,Year)}$	Process efficiency standard policy ($/Btu). Assign a process efficiency standard policy which establishes the minimum level of process efficiency chosen by the model.
6.	PEMM$_{(Enduse,Tech,EC,Area,Year)}$	Process Energy Efficiency Maximum Multiplier ({$/Btu}/{$/Btu}). Parameter used to modify efficiency curve.
7.	PCCMM$_{(Enduse,Tech,EC,Area,Year)}$	Process Capital Cost Maximum Multiplier ($/$). Parameter used to modify capital cost curve.
8.	DEStdP$_{(Enduse,Tech,EC,Area,Year)}$	Device efficiency standard policy (Btu/Btu). Assign a device efficiency standard policy which establishes the minimum level of device efficiency chosen by the model.
9.	DEMM$_{(Enduse,Tech,EC,Area,Year)}$	Parameters of device efficiency curves. DEMM – reflects the change in device efficiency in the appliance efficiency program (Btu/Btu) Assigning a value to the multipliers, DEMM will adjust the efficiency curves up or down.

No.	Policy Variable Name	Demand Sector Policy Variable Description
10.	DCMM$_{(Enduse,Tech,EC,Area,Year)}$	Parameters of device capital cost curves. DCMM – reflects the policy changes in device capital costs in the appliance efficiency program ($/$) Assigning a value to the multipliers, DCMM will adjust the capital cost curves up or down.
11.	DPL$_{(Enduse,Tech,EC,Area,Year)}$	Physical life of devices (Years). Reduce lifetime of devices (DPL) to allow for more efficient device to quickly replace existing stock.
DSM Program Impacts		
12.	DSMEU $_{(Enduse,EC,Area,Year)}$	Exogenous DSM represent impact of DSM programs (TBtu/Yr). Provides a direct reduction in electric demand in affected sectors and areas.
13.	PEDC $_{(ECC,ReCo,Year)}$	Real Electricity Delivery Charge ($/MWh). Electric delivery charge reflects electric systems benefit charge.
Stock Levels Policies		
	PCPL$_{(ECC,Area,Year)}$ PEPL$_{(Enduse,Tech,EC,Area,Year)}$ DPL$_{(Enduse,Tech,EC,Area,Year)}$	Physical Life of Production Capacity (Years). Physical Life of Process Energy Requirements (Years). Physical Life of Devices (Years). The physical lifetime variables are used to calculate the retirement rate of the capital stock (production capacity, process energy, or device energy). For quicker turnover of capital stock, physical lifetimes of any of the types of capital stock can be decreased. For example, policies that promote early scrappage of devices, such as vehicles, in favor of new efficient devices can be applied by adjusting the device physical lifetime variable.
Retrofits Policies		
	RPMSM0$_{(Enduse,Tech,EC,Area,Year)}$	Retrofit Process Energy Marginal Market Share Multiplier/ Non-Price Factor ($/$). This variable represents the non-price propensity toward or barrier to a specified technology (end use-fuel combination). It is endogenously calculated during the historical calibration and assigned future values based on historical levels. Modifying the value of MMSM0 overwrites the endogenously-calculated value assigned during calibration and can be used to promote specific technologies compared to the business-as-usual case.
	XRPMSF$_{(Enduse,Tech,EC,Area,Year)}$	Exogenous Retrofit Process Energy Marginal Market Share Fraction by Device ($/$). If the expected market share needs to be set to a specified value, such as to match an exogenous forecast, an exogenously-specified marginal market share can be assigned.

No.	Policy Variable Name	Demand Sector Policy Variable Description
	$\text{RDMSM0}_{\text{(Enduse,Tech,EC,Area,Year)}}$	Retrofit Device Energy Marginal Market Share Multiplier/ Non-Price Factor ($/$). This variable represents the non-price propensity toward or barrier to a specified technology (end use-fuel combination). It is endogenously calculated during the historical calibration and assigned future values based on historical levels. Modifying the value of MMSM0 overwrites the endogenously-calculated value assigned during calibration and can be used to promote specific technologies compared to the business-as-usual case.
	$\text{XRDMSF}_{\text{(Enduse,Tech,EC,Area,Year)}}$	Exogenous Retrofit Device Marginal Market Share Fraction by Device ($/$). If the expected market share needs to be set to a specified value, such as to match an exogenous forecast, an exogenously-specified marginal market share can be assigned.
Conversion Policies		
	$\text{CMMSM0}_{\text{(Enduse,Tech,EC,Area,Year)}}$	Conversion Marginal Market Share Multiplier/ Non-Price Factor ($/$). This variable represents the non-price propensity toward or barrier to a specified technology (end use-fuel combination). It is endogenously calculated during the historical calibration and assigned future values based on historical levels. Modifying the value of CMMSM0 overwrites the endogenously-calculated value assigned during calibration and can be used to promote specific technologies compared to the business-as-usual case.
	$\text{XCMSF}_{\text{(Enduse,Tech,EC,Area,Year)}}$	Exogenous Conversion Marginal Market Share Fraction by Device ($/$). If the expected market share needs to be set to a specified value, such as to match an exogenous forecast, an exogenously-specified marginal market share can be assigned.

4. Methodology for Common Electric Supply Sector Policies

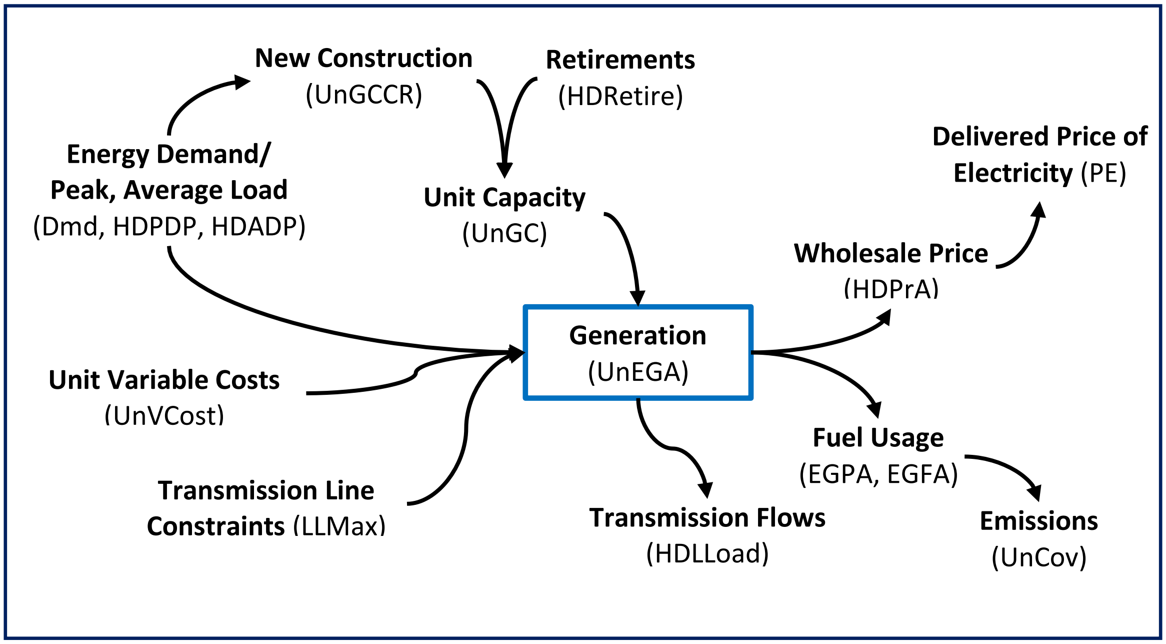
Policies applied to the electric utility sector commonly include the retirement or construction of new generating capacity and implementing a renewable portfolio standard as described below.

Capacity Retirements or Construction of New Capacity – Electric capacity and generation is represented at the individual generating unit level. The existing and known planned generating units and their defining characteristics (plant type, location, online year, retirement year, capacity, capital and operating costs) are inputs to the model. To retire capacity of any generating unit involves simply setting the retirement year. To add new capacity as part of a policy, there needs to be an existing generating unit (or set of generating units) to assign new capacity to. For any defined generating unit, policies are able to be constructed to add new capacity or remove capacity as desired.

Renewable Portfolio Standard – A renewable portfolio standard (RPS) policy establishes a minimum required amount of renewable capacity and/or generation. Depending on the specifics of the policy, the RPS displaces conventional generation and creates new renewable capacity as well as dispatches renewable generation based on certain criteria, such as percentage of electricity sales.

The model relationships that apply to electric generation and capacity are shown in Figure 15. The generation of each unit is determined based on an optimization, minimizing the system costs given the units' variable costs, generating capacity and transmission line capacities. As can be seen in the diagram, modifying any aspect of the electric generating system could impact overall fuel usage, transmission flows (including imports and exports), emissions, and the price of electricity.

Figure 15. Electric Generation Model Relationships



4.1. Policies that Modify Generating Capacity

Simulating policies that modify the construction and/or retirement of electric generating capacity, such as a program designed to promote the retirement of coal generation, is facilitated by the fact that ENERGY 2020 represents individual electric generating units across twenty-four plant types and tracks a wide variety of characteristics for each of the generating units. Individual generating units are defined in the input data by way of an Access database containing the characteristics of each, including online year, retirement year, plant type, location, and capacity.

Retiring generating capacity: To retire electric generating unit capacity, the following variable is modified:

- **Retirement dates (UnRetire)**: Assign a retirement year to each of the individual generating units that are to be retired. For example, if specific coal units are going to be retired in the year 2020, then assign UnRetire=2020 for all relevant coal units.

Adding new capacity: Because capacity is represented with individual generating units, new capacity needs to be assigned to a unit that that has been defined in the input data. Assuming that new capacity is to be added to existing generating units, variables to modify when building new capacity consists of the following:

- **New capacity construction (XUnGCCI):** Assign the amount of new capacity to construct to the variable XUnGCCI for selected generating units. Construction of new generating capacity occurs over several years to allow for construction delay (an input to the model). As a result, to add new capacity in the year 2020, the new capacity construction variable would be assigned a value a few years before the year 2020 depending on the type of plant and the years assigned to build that plant type. As an example, the construction delay (CD) is set to two years for combined cycle plant types, five years for hydro and twelve years for nuclear.

4.2. Policies that Define a Renewable Portfolio Standard (Renewable Goal)

A policy to build an RPS impacts the new construction in the model. Several policy variables exist in the model to assign a specific amount of renewable capacity. Options are available to the user to either add generation to existing plants directly or to specify a percentage of endogenous renewable generation in the forecast. The variables consist of the following:

- Renewable fraction (RnFr)
- Switches to exogenously build renewables (RnOption)
- Specified amount of new renewable capacity (XUnGCCI)
- Renewable market share non-price factors and variance factors to promote construction (RnMSM, RnVF)

Adding new capacity, retiring capacity, or establishing renewable goals all impact the behavior of the generation dispatch routines and the expected impacts include the following:

- Direct impacts: Changes in generating capacity; changes in capacity of specific plant types; Retirements of higher-emission plant types
- Indirect impacts: Change in total emissions; change in electricity prices; change in electric utility expenditures

Sample files that modify generating capacity are listed below and located in ENERGY 2020's 2020Model subdirectory:

- AccCoalRetire_2030.txp: In this policy all coal units must retire by 2030. This assumes other units are already retired by their existing regulatory or pre-2030 technical retirement dates.
- UnitAddCap_SK.txp: Saskatchewan renewable capacity added for coal retirements.

4.3. Summary of Key Electric Sector Policy Variables

The most commonly-used policy variables in the electric sector are identified in Table 6**Error! Reference source not found.** and cover policies applied to electric generation for individual generating units or across plant types (such as coal, nuclear, or renewables), constructing new capacity or retiring capacity, and establishing exogenous flows between nodes to simulate contracts.

Table 6. Electric Sector Common Policy Variables

No.	ENERGY 2020 Variable	Electric Sector Policy Variable Description
Construction of New Capacity		
1.	$XUnGCCI_{(Unit,Year)}$	Generating Capacity Initiated (MW). Some policies specify new capacity construction, often as replacement for retired generating capacity or to fill gaps in a renewable portfolio standard.
Retirement of Existing Capacity		
2.	$UnRetire_{(Unit,Year)}$	Retirement Date (Year). Some policies mandate retirement dates for some generating units, frequently Coal units.
Renewable Portfolio Standard (RPS)		
4.	$RnOption_{(Area,Year)}$	Renewable Expansion Option (Switch). Switch to exogenously build renewables (1=Local RPS, 2=Regional RPS, 3=FIT)
5.	$RnFr_{(Area,Year)}$	Renewable fraction (GWh/GWh). This is the specified standard set in a renewable portfolio standard policy.
6.	$RnMSM_{(Plant,Node,GenCo,Area,Year)}$ $RnVF_{(Area,Year)}$	RnMSM - Renewable Market Share Non-Price Factors (GWh/GWh) RnVF - Renewable Market Share Variance Factor ($/$) Assign or modify values of renewable market share non-price factors and price variance factors to promote construction. These are the non-price and price factors of the qualitative consumer choice equation to calculate marginal market share.
7	$FIT_{(Plant,Area,Year)}$	Feed-In Tariff for Renewable Power (nominal $/MWh). Setting a value for this variable allows for feed-in tariffs to promote renewable generation construction.
Contract Flows (Exogenous Flows Across Transmission Lines)		
8.	$HDXLoad_{(Node,NodeX,TimeP,Month,Year)}$	Exogenous Loading on Transmission Lines (MW). Contract flows from Muskrat Falls to New England are reduced to allow NS to increase their purchases.

5. Methodology for Common Emissions-Related Policies

The most common policies implemented in the model designed to directly reduce emissions are carbon taxes and policies which set a targeted cap on emissions. Appendix 2 discusses ENERGY 2020's approach to modeling each of the cap-and-trade concepts discussed below.

In recent years, increased policy analysis has been geared toward emissions reductions. The ability of ENERGY 2020 to simulate individual components of energy supply and consumption allows the ability to perform a wide range of potential environmental policies.

Energy and Emission Taxes and Incentives have been applied to reduce emissions by incentivizing producers and consumers to move to less energy-intensive processes. ENERGY 2020 was developed with a robust consumer choice mechanism that allows for consumers to choose which energy type to use when deciding which type of car, furnace, industrial boiler, etc to use. The decisions are driven both by price considerations, which are altered using taxes or incentives, and historical preferences.

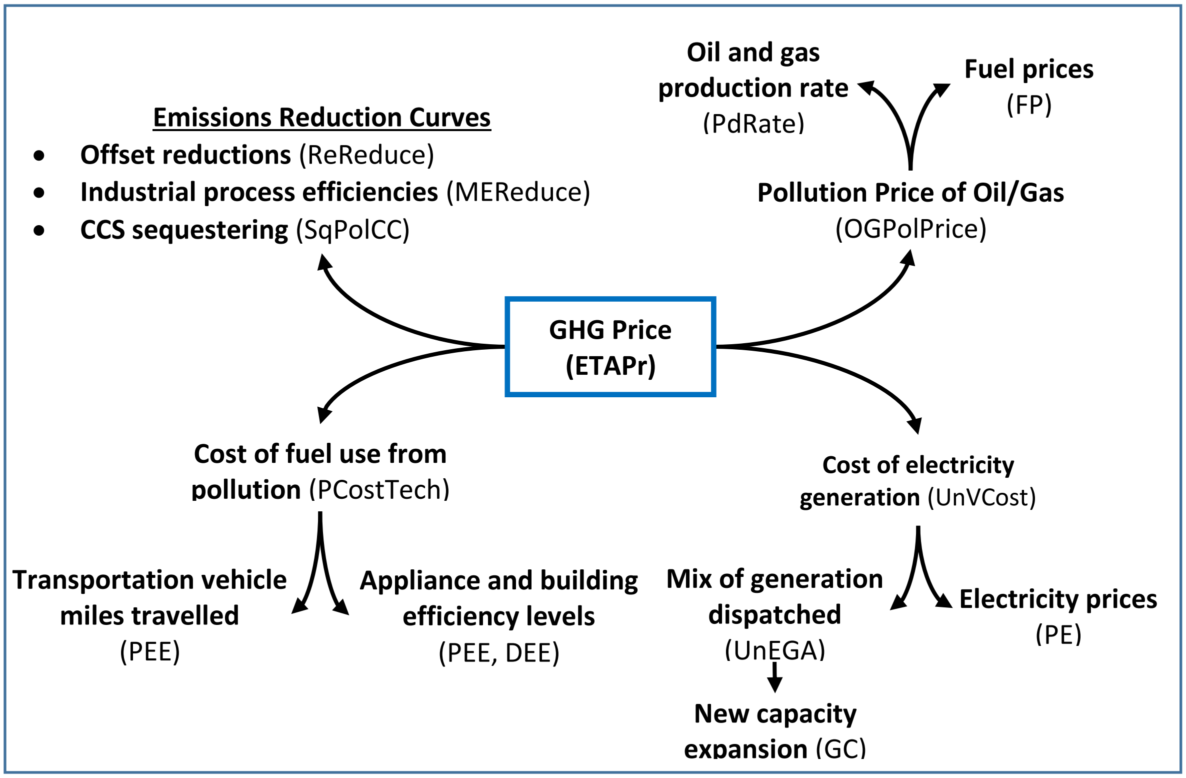
Clean Air Standards enacted to reduce greenhouse gases or criteria air contaminates (CACs) through improvements to efficiency or the installation of emission mitigation devices, such as smokestack scrubbers. Costs of installing and maintaining mitigation devices are developed and passed through a macroeconomic model to determine the impacts of the policy on the economy. If a standard is applied to a sector that produces energy, such as electric generators, then the cost impact is passed into consumer energy prices. Electric generators are individually modelled so that the impact of the standard on a single plant can be assessed to help determine whether the generator will spend to meet the standard or stop operating. This approached has been used to look at various coal plant regulations and electric performance standards across Canada.

Carbon Cap and Trade Systems where emission credits are granted or auctioned to various combinations of economic sectors and areas. Industries can choose either to reduce emissions or purchase credits dependent both on costs and on the structure of the regulatory system, such as credit banking. ENERGY 2020 has been used to analyze greenhouse gas emission caps in Alberta, specifically in the oil and gas sectors, and Quebec.

5.1. Emissions-Related Model Relationships

Similar concepts apply within ENERGY 2020 for implementing emissions-related taxes or targets. Each type of policy assigns a cost to emissions. This cost then feeds directly into several structures in the model, including fuel prices, oil and gas production rates, levels of offset reductions, levels of carbon capture and storage (CCS), industrial process efficiencies, appliance and building efficiencies, and vehicle distance travelled. Figure 16 illustrates the key direct impacts of assigning a cost to emissions.

Figure 16. Direct Impacts of Emissions Price (Tax or Permit Prices)



5.2. Defining Emissions-Related Policies

To set up an emission policy in ENERGY 2020, the structures that are to be covered by the emissions price must be defined by answering the following questions:

1. Years: what year does the price start?
2. Areas: which areas are impacts?
3. Pollutants: which pollutants are covered?
4. Sectors: which sectors are included?
5. Electric utility industry: Are emissions from 100% of all existing electric generation units covered? Are new units' emissions included?
6. Cogeneration: Is generation from cogeneration covered?

7. Emissions price: What type of system is this (carbon tax, cap-and-trade, simple emissions target). What is the price of emissions in \$/Tonne? Is it gradually phased in or fully applied in the initial year?

Carbon Tax: A carbon tax is a tax based on the level of greenhouse gas emissions and creates a price signal to reduce overall emissions through various approaches, including reducing fuel consumption, increasing fuel efficiency, using cleaner fuels, and using new technologies. By applying a tax on emissions within ENERGY 2020 every ton of emissions generated from covered sources gets taxed.

Emissions Goal: A policy that places a cap on emissions could be defined as a simple mass-based or emissions intensity target or could be defined as a more complex cap-and-trade system. For instance, a limit to carbon emissions can be set directly and the model will generation reductions to meet the cap. ENERGY 2020 has the structures in place that allows for simulation of all levels of complexity.

Cap-and-Trade Systems: ENERGY 2020 simulates a cap-and-trade system by establishing a greenhouse gas emissions allowance price and allowing each sector to respond to the price. If the GHG target is not met, then ENERGY 2020 increases the price and allows each sector to respond a second time. The model continues to iterate until a solution is found.

GHG cap-and-trade systems are a form of regulation in which each entity which produces a unit of GHG must provide a GHG allowance (or permit) to the regulatory authority. These allowances are obtained through purchases from a GHG market or may be allocated freely to participants. The total number of allowances (either allocated freely or auctioned to the market) is controlled by the regulating authority. The regulatory authority will set the number of allowances equal to the desired GHG emission goal. A market for GHG allowances is created from which any GHG entity can buy or sell allowances as needed. This market will establish a price for allowances which will clear the market and thus meet the GHG goal.

A cap-and-trade system design has multiple structural concepts which must be taken into account when attempting to develop a comprehensive simulation.

- Emissions coverage – geographic, economic sectors and fuels, pollutants
- Emissions goal – historical, forecast, intensity - goals by sector
- Allocated allowances (gratis permits) – historical, forecast, intensity
- Offsets – local, domestic, international, government, offset limits, offset prices
- Allowance price limits (minimum, maximum)
- Allowance reserves

- Banking and borrowing allowances
- Allowance revenues recycling
- Macroeconomic feedback

ENERGY 2020 is able to handle having multiple and varying coverages defined within the model. For example, if we wanted to define a carbon tax for Alberta that has a different price and different set of pollutants than Quebec, then different emission markets would be defined within ENERGY 2020. Markets are used to define the pollutants, areas, and sectors covered by a tax. The model is designed to hold up to 220 different Markets. Several variables are defined by market and assign which equations are calculated within the model. Appendix 2 lists the variables that need to be assigned a value in order to set up the coverage criteria and emission price for carbon tax policies or emissions targets.

5.3. Summary Key Emissions Policy Variables

The most commonly-used policy variables used to directly reduce emissions, including carbon taxes and setting emissions targets or limits are listed in Table 7.

Table 7. Emissions-Related Policy Variables: Setting a Carbon Tax or Emissions Limit

No.	ENERGY 2020 Variable	Emissions Reduction Policy Variable Description
Carbon Tax/GHG Tax		
1.	$XETAPr_{(Market, Year)}$	Exogenous Cost of Emission Trading Allowance ($/Tonne). This variable sets a basic carbon tax. Note, for a carbon tax, the “Market” in which tax is applied needs to be defined (see policy variables listed in “Defining Emissions Coverages” below)
Emissions Targets		
2.	$XGoalPol_{(Market,Year)}$	Pollution Total Goal (Tonnes/Yr). Emissions limit mass based for electric utilities; this creates a pollution constraint in the linear program during dispatch.
3.	$PollutionLimit_{(Poll,Area,Year)}$	Electric Utility Pollution Limit (Tonnes). Absolute pollution limits for electric generation.
4.	$XPolCap_{(ECC,Poll,PCov,Area,Year)}$	Exogenous Emissions Cap (Tonnes/Yr). Economic sector based emissions cap.
5.	$XUnGCCC_{(Unit,Year)}$	XUnGCCC - Generating Unit Capital Cost (Real $/KW) Modify value of capital cost of generating unit if appropriate due to needing to install emissions reduction equipment.
6.	$XUnRCC2_{(Unit,Poll,Year)}$	Pollution Reduction Capital Cost ($/(Tonnes/Yr)) Assign value to capital cost of emissions reduction equipment if appropriate.
Defining Emissions Coverage Market (Areas, Pollutants, Industries, etc.)		

No.	ENERGY 2020 Variable	Emissions Reduction Policy Variable Description
1.	$\text{Enforce}_{\text{(Market)}}$	First Year Market Limits are Enforced (Year) When limits are enforced, Tax Rates are in effect.
2.	$\text{ETABY}_{\text{(Market)}}$	Beginning Year for Emission Trading Allowances (Year)
3.	$\text{AreaMarket}_{\text{(Area, Market, Year)}}$	Areas included in market (1=included)
4.	$\text{PollMarket}_{\text{(Poll, Market, Year)}}$	Pollutants included in market (1=included)
5.	$\text{PCovMarket}_{\text{(PCov,Market,Year)}}$	Types of emissions covered (1=included) (Energy, Oil, Natural Gas, Cogeneration, Non-Combustion, Process, Venting, Flaring)
6.	$\text{ECCMarket}_{\text{(ECC, Market, Year)}}$	Economic categories included in market (1=included) Miscellaneous ECC is never included in a market because that slot holds government revenues.
7.	$\text{ECoverage}_{\text{(ECC,Poll,PCov,Area,Year)}}$	Sectors, pollutants, emissions types, and areas covered. (1=covered). Note that all ECCs, Polls, PCovs, and Areas across all markets being defined get a value of 1.
8.	$\text{UnCoverage}_{\text{(Unit, Poll, Year)}}$	Coverage of existing generating units (1=covered). Note that any existing unit that is covered in any of the markets is flagged with UnCoverage=1.
9.	$\text{CoverNew}_{\text{(Plant,Poll,Area,Year)}}$	Fraction of new plants covered in the emissions market (1=100%)
10.	$\text{PolCovRef}_{\text{(ECC,Poll,PCov,Area,Year)}}$	Reference Case Covered Pollution (Tonnes/Yr). If policy case, assign value to covered emissions from the reference case. Assign a value to PolCovRef if current run is a policy run to be compared to the reference case. This variable is relevant primarily for cap-and-trade runs rather than carbon tax.
11.	$\text{CapTrade}_{\text{(Market,Year)}}$	Emissions cap-and-trading switch (1=trade; 2=cap only; 5=GHG market). Set this switch equal to 5 for carbon tax only. Equations for a carbon price with no specific caps or targets are run when CapTrade=5.
12.	$\text{CBSw}_{\text{(Market,Year)}}$	Market Switch (0=CT no Auction, 1=CT with Auction, 2=Tax)

6. Other Specific Policy Examples

Below are several specific examples of real-world policies that can be simulated using ENERGY 2020, including a general overview of the modeling methodology, and the relevant input data or information that would be required in each case to refine the analysis. The specific policy examples include:

Section	Sector Impacted	Type of Policy
Section 6.1 Transportation Policies	Oil and gas industry	Improved in-situ extraction Green fracking Venting and flaring
Section 6.2	Transportation sector	Electric vehicles Biofuels Increased efficiency vehicles
Section 6.3	Industrial sector	Carbon capture and storage Fuel switching Process optimization
Section 6.4	Electric utility industry policies	Renewable generation Geothermal power plants
Section 6.5	Residential and commercial policies	Appliance efficiency standards Building standards Net zero buildings

6.1. Oil and Gas Policies

Improved In-Situ Extraction

Description: Incorporate an improved in-situ extraction technology that reduces total GHG emissions by 50% and/or reduces extraction emissions by 80% at break-even cost of $52/barrel WTI. The characteristics of this new technology are that it is cheaper, produces less GHG emissions, produces less process emissions, and uses less water than the standard SAGD processes represented currently in the model.

Modeling Methodology: There are two options for modelling this new in-situ technology in ENERGY 2020. Determining which option to choose depends on the importance of tracking the individual performance of this new technology. The first option is to introduce the new technology into an existing ENERGY 2020 economic sector and adjust the efficiency and emissions levels of the industry to reflect the presence of the new technology. With this option the new in-situ technology would be assimilated as part of the *SAGD Oil Sands* industry currently represented in the model. The expected penetration of the new technology would be used to shift the price response curve upward, increasing the overall efficiency and capital costs of the SAGD Oil Sands industry at the same fuel price level over time. Additional adjustments would be made to the process emissions coefficients of that given industry, as well as the coefficient for water usage.

The second option assumes a high importance of tracking this individual new technology. If tracking the new technology is a priority then a new industry would be created in the model to represent this new in-situ technology. The new sector would be created using available data from a similar industry (*SAGD Oil Sands*) and information on the improvements of the new technology. The production of oil with this new technology would drive the energy demand and emissions from the new sector.

Information/Data Required: Input data that would be required to incorporate the new in-situ technology consists of the following:

- Description of program, including start and end dates, expected emission reductions, fixed and variable costs
- Change in marginal efficiency from standard SAGD technology
- Change in marginal capital cost from standard SAGD technology
- Change in water usage per barrel of oil
- Change in coefficient on process emissions for VOCs
- Expected production from new technology

If the technology is incorporated as part of the *SAGD Oil Sands* sector, then the production rate of the new technology would be used to generate an adjustment to the technology parameters inside the *SAGD Oil Sands* sector. Different levels of production would result in different adjustments to the technology parameters of the industry.

Green Fracking

Description: Green Fracking consists of new fracking technologies that are environmentally cleaner than traditional methods. They consist of improvements, such as using less or no water, replacing harsh chemicals with more benign mixtures, replacing diesel-powered drilling equipment with natural gas or solar-powered equipment, or capturing methane that would otherwise escape. Due to current regulations, methane must either be captured or flared. The green fracking technology, called Reduced Emissions Completions (REC), to be modeled requires the use of special equipment to collect the gas during the well-completions. It is assumed that the REC equipment is only able to capture 90% of methane, and the remaining 10 still need to be flared.

Modeling Methodology: ENERGY 2020 will test the impact of Green Fracking by incorporating the higher efficiency, the lower emission factors and water use, the use of solar and natural gas drilling equipment. These parameters will be weighted into the current parameters base on the fraction of new production which is expected to use Green Fracking. This fraction can be varied between policy runs to test the impact of different levels of Green Fracking penetration. The Green Fracking penetration can be expressed as production or as number of wells times production per well.

Information/Data Required: Input data that would be required to incorporate Green Fracking technology would consist of the following:

- Description of Green Fracking technology implemented
- Change in marginal efficiency
- Change in marginal capital cost
- Change in water usage per barrel of oil
- Change in emission coefficients
- Capital cost and generation from solar units
- Capital cost and efficiency of methane capture equipment
- Expected number of wells using Green Fracking
- Expected production from each Green Fracking well

Venting and Flaring

Description: Incorporate programs that reduce emissions from flaring and venting at a level that meets or exceeds the US regulation, including options for VOC capture. Flaring is the burning of natural gas in an open flame and venting is direct release of natural gas or carbon dioxide into the atmosphere. Venting and flaring waste natural gas and emit carbon dioxide, methane, carbon monoxide, nitrous oxide, particulate matter, and VOCs. The policies to be examined include leak detection and repair, leaks from pneumatic devices, and venting methane.

Modeling Methodology: Within ENERGY 2020, venting and flaring emission reduction curves already exist as a function of CO2 prices. In order to meet a specified level of compliance, an emissions standard would be added to force the compliance level. Venting and flaring emission reduction curves can be applied to any of the oil and gas industries. In addition to emission reduction curves, venting reduction capital cost curves also are incorporated. The cost curves currently used assume the following:

- Recovered value of methane, ethane and VOC's is approximately $4/GJ;
- Costs for gas conservation: $150K capital cost and $10K O&M cost;
- Costs for flaring: $35K capital cost and $20K O&M cost
- Use of conservation/flare: 50%/50% distribution, except for H-AdminB crude facilities, where 100% flaring was used due to lack of gas pipeline tie-in availability.

The emission reduction curve has the following form where the fraction of venting reduced is calculated using the following formula:

$$\text{Fraction of Emissions Reduced} = C_0/(1+A_0*\text{eCO2Price}\hat{}B_0)$$

The capital cost curve is calculated using the following formula:

$$\text{Capital Cost} = C(cc)_0/(1+A(cc)_0*\text{eCO2Price}**B(cc)_0)$$

Where A_0, B_0, and C_0 are the coefficients of the emission reduction curve and $A(cc)_0$, $B(cc)_0$, and $C(cc)_0$ are the coefficients of the capital cost curve. Examples of coefficients used for light oil mining, heavy oil mining, and the primary oil sands industry are shown in the tables below for both the emission reduction and capital cost curves.

Venting Emission Reduction Curve Coefficients ($/Tonne)	
Light Oil Mining	**Heavy Oil Mining & Primary Oil Sands**
A_0 = 1.85601 B_0 = -0.78771 C_0 = 0.92446	A_0 = 1.87465 B_0 = -0.60289 C_0 = 0.93798

Venting Reduction Capital Cost Curve Coefficients ($/$)	
Light Oil Mining	**Heavy Oil Mining & Primary Oil Sands**
$A(cc)_0$ = 3.17029 $B(cc)_0$ = -0.53467 $C(cc)_0$ = 1591.937	$A(cc)_0$ = 8.56275 $B(cc)_0$ = -0.66629 $C(cc)_0$ = 1317.020

The fraction of methane (CH4) captured from venting reductions is assumed to be equal to 0.50. The emission factors assumed for venting reductions for CO2 and VOC and are listed in the table below in tonnes per tonnes of methane for the light oil mining, heavy oil mining, and primary oil sands industries. Additionally, flaring venting emissions reduces methane (CH4), but increases CO2 only and the coefficients are listed below.

Venting Reduction Emission Factors (Tonnes/Tonne CH4)			**Emission Factors for Flared CH4 (Tonnes/Tonnes)**
Industry Impacted	**CO2**	**VOC**	**CO2**
Light Oil Mining	0.1887	0.0573	2.4014

Heavy Oil Mining, Primary Oil Sands	0.4057	0.0528	1.5041

The coefficients depend on the assumed gas speciation profiles as listed below.

		Light Oil	**Heavy Oil**
Venting Gas Component Concentrations		100%	100%
CO2		7.79%	2.89%
CH4		40.16%	72.29%
C2H6		14.70%	6.78%
VOC:		34.80%	12.89%
C3H8	Propane	13.86%	4.94%
C4H10	Butane	12.64%	3.00%
C5H12	Pentane	5.35%	1.54%
C6H14	Hexane	2.15%	0.67%
C7H16	Heptane	0.20%	0.89%
C8H18	Octane	0.20%	0.59%
C9H20	Nonane	0.20%	0.67%
C10H22	Decane	0.20%	0.59%
NOX		2.80%	5.16%

Information/Data Required: The information or data required to model a venting and flaring emission reduction program consists of the following:

- Description of venting and flaring program
- Targeted amount (or percent) of flaring and venting emission reductions
- Any changes to the assumptions listed above

6.2. Transportation Policies

Electric Vehicles

Description: Increase adoption of electric vehicles – either increasing % of annual vehicle sales or total % of vehicle stock.

Modeling Methodology: Consumer choice theory equations are used to simulate a consumer's choice in purchasing a new car. The decisions are based on marginal capital cost, efficiency, and non-price factors. In order to reach a target for new electric car sales, an exogenous market share fraction is assigned into the equation. Within ENERGY 2020, consumers are able to change technologies (such as switching to an electric vehicle) whenever an energy device (automobile) reaches the end of its useful life. The model also has mechanisms in place which would allow consumers to change technologies before the end of its useful life if desired.

Information/Data Required: The information or data required to model an electric vehicles program consists of the following:

- Description of electric vehicles policy
- Target market share by when and which geographic areas
- Efficiency and capital cost assumptions of all vehicle types

Biofuels

Description: Increase the percent of bio-based fuels in mix (for both gasoline and diesel)

Modeling Methodology: The transportation model separates transportation vehicles types based on their primary fuel type and size. For example, there are types available for light-duty gasoline cars, light-duty diesel cars, light-duty gasoline trucks, and so on. The model uses historical data to determine the fuel used to meet energy demands for each technology type. Electric vehicles might be powered only by electricity, but gasoline vehicles can have a mixture of gasoline and ethanol. The ratio of fuel type used for each technology type can be adjusted in the forecast to simulate the impacts of policies that promote the introduction of more biofuels into the fuel mix. Each fuel type in the model has an associated emissions coefficient, so shifting fuel usage can alter the emissions forecast as well as reduce the primary fuel demand to favor more biofuel demand.

Information/Data Required: The information and/or data required to incorporate an increase of the percent of bio-based fuels include the following:

- Description of program including the implementation years
- Fractions for biofuel usage compared to gasoline or diesel
- Any secondary impacts, such as increase in vehicle prices, if applicable

Increased Efficiency Vehicles

Description: Increase baseline efficiency of internal combustion vehicles (through a variety of pathways – lightweight vehicles, high performing engines and drivetrains, etc.)

Modeling Methodology: The transportation model inputs historical efficiency data which includes the impact of historical efficiency standards. Transportation demand is forecasted using either a default efficiency standard continued from the most recent historical standard, or a user-specified efficiency standard forecast to set a higher floor for efficiency in the future. The model allows for consumers to opt to purchase vehicles at a higher aggregate efficiency than the standard to produce a response if fuel prices are very high in the forecast. In most cases, the efficiency selected is equal to the standard specified. An increase in the efficiency standard will produce lower energy consumption and emissions, lower spending on fuel, and a higher vehicle price. These impacts are introduced to the forecast over time as old vehicles are scrapped and are replaced with vehicles subject to the standard.

Information/Data Required

The data required to implement increased efficiency vehicles include the following:

- Program description, including years that the efficiency standard is in effect
- Estimate of the standard, either vehicle efficiency or in rate of improvement from current values, at the technology levels used in the model
- Estimate of the policy impact on vehicle cost

6.3. Industrial Sector Policies

Carbon Capture and Storage

Description: Incorporate Carbon Capture and Storage (CCS) for large point source emitters in Cement, Steel, and Refineries industries.

Modeling Methodology: ENERGY 2020 currently has CCS curves in the model for several industries. These curves output the level of CCS given a CO2 price and the capital costs. There is a model switch indicating whether to use the CCS curves to determine the level of CCS purchased as a function of CO2 price or to exogenously input a level of CCS instead of using the CO2 price.

Information/Data Required: The information and/or data required to include a specific carbon capture and storage program in the model include the following:

- Description of program expectations
- Electricity penalty and information on provincial specifications
- Level of CCS desired or carbon price per sector, depending on methodology chosen
- Capital costs of CCS by sector
- Learning by doing curve if appropriate

Fuel switching

Description: Incorporate fuel switching policy (to bio-based fuels, waste, and natural gas) for Cement, Steel, and other heavy users of coal and petroleum coke.

Modeling Methodology: The model uses historical energy demand inputs to calculate the market share of each technology for each combination of economic sector, area, end use, and year. Consumer choice theory is applied to determine the impact of price-related factors versus other, non-price factors when the consumers picked between technologies historically. These relationships are carried forward into the model forecast, where changes in fuel prices have a varying level of impact on the market shares of technologies based on the market share history. To simulate a policy which promotes movement away from historical trends, non-price factors are adjusted for each economic sector. This non-price factor adjustment allows for switching to fuel types not frequently chosen historically simulating anticipated greater availability in the forecast.

Information/Data Required: The information and/or data required to incorporate fuel switching include the following:

- Description of program, including implementation years
- Expected market share penetration of the emphasized technology type
- Details about the emphasized technology, including efficiency and cost data, if the technology has little detail in the historical data.

Process Optimization

Description: Incorporate a process optimization into the industrial sector via waste heat use, CHP etc.

Modeling Methodology: There are a variety of ways to model this process optimization depending on the information available and a definition of optimization (who is optimizing?). For example, the higher efficiency of the optimized process could be input to see the impact. Alternatively, several industrial processes could be incorporated to determine which process optimizes the desired variable.

To determine a desired mix of types of process optimizations, a set of potential portfolios would be developed and run though the model to determine the ones that meet the desired criteria. The portfolios would include various modifications to assumptions, such as efficiencies, market shares of cogeneration, and level of solar PV.

Information/Data Required: The data required for implementing process optimization would include the following:

- Description of potential process optimization options
- Industries impacted, market shares, efficiencies

6.4. Electric Power Industry Policies

Renewable Generation

Description: Incorporate a program that increases the percent of electricity production from variable renewables (wind, solar PV).

Modeling Methodology: Renewable plants are modeled as resources with a diverse set of cost properties so hydro, wind, and solar resources can all be developed at the same time. The level of non-emitting units constructed increases until the target is reached.

The type of non-emitting new capacity to be built is selected using a consumer choice function in which utilities are highly sensitive to cost. A single "least cost" resource is not selected for development; instead, a more diverse selection is built with the lowest cost option being dominant, but not exclusive. As an alternative method of increasing renewable generation, new renewable capacity can be input to the model exogenously.

I*nformation/Data Required:* The information or data required to model an increase in renewable generation consists of the following:

- Description of the program, including start dates, types of renewables to increase, geographic areas affected, and types of generation included (electric utility, industrial generation)
- Target as a percent of electricity consumption or electricity sales
- Desired fractions of renewable generation, if appropriate
- If an exogenous set of new renewables is desired, specify exogenous new renewable capacity as new electric generating units in the model.

Geothermal Power Plants

Description: Incorporate geothermal baseload plants into the model in a number of test locations to account for impact on a different generation mixes across provinces.

Modeling Methodology: The methodology used to increase the generation of geothermal plants is similar to the methodology for increasing the use of renewables. Each individual existing electric generating unit in Canada is exogenously specified along with its characteristics (location, plant type, capacity, fixed and variable costs, outage rate, etc.). To add one or more geothermal unit to the model, exogenously specify units could be input along with a potential capacity limit for geothermal plants. The geothermal plants then would be included in the pool of generation resources to be dispatched based on costs or based on an externally-specified target.

Information/Data Required: To incorporate one or more test locations for geothermal plants into ENERGY 2020 the following information or data would be required:

- Description of policy case, including start and end dates, location, and targets if they exist.
- Characteristics of new geothermal units to add to the model – location (province), capacity, fixed and variable costs, outage rate, and heat rate.
- Maximum potential for geothermal generating capacity
- Target percentage of electric generation, if desired

6.5. Residential and Commercial Policies

ENERGY 2020 simulates the energy efficiency of building shells (Process) and appliances (Device) for separate energy-related end uses. This enables us to have a building code for a home unique from the appliance-level efficiency standard. Standards can be applied down to a specific level of detail to simulate real-world policies. For example, different standards can be applied to natural gas furnaces, oil furnaces, and to the space heating portion of the building shell simultaneously. The stocks and flows portion of the model methodology allows for the impact of new efficient equipment or buildings to gradually cycle into each economic sector over time to replace retiring devices to produce a realistic forecast of energy and emissions impacts. Increasing the rate of this turnover can be included as part of a policy. The model also includes options for retrofitting existing building stock.

Residential and Commercial Appliance Efficiency Standards

Description: Incorporate efficiency standards or awareness programs to reduce energy consumption in new appliances.

Modeling Methodology: The efficiency and cost of new devices selected by consumers in the forecast is produced as an output based on fuel prices and input historical data. The model has the ability to set a floor for the consumer selected efficiency, where devices below a certain level of work output per energy input are not available for selection. A policy with a significant efficiency floor will produce energy savings and fuel purchase savings for consumers with the trade-off of higher initial capital costs when compared to a reference case with no standard. The model simulates the existing stock of equipment along with retirements and new purchases, allowing for the impact of the program to be evaluated over time as new efficient devices replace less efficient retiring equipment.

Information/Data Required: Description of the devices covered by the program and implementation years.

- Description of the standard, either by rate of efficiency or rate of improvement from current stock, at the level of detail available in the model.
- Estimation of expected changes in capital costs produced as an impact from the policy.

Residential and Commercial Buildings Efficiency Improvements

Description: Improvements to the overall energy efficiency of a residential or commercial building shell.

Modeling Methodology: The energy efficiency of building shells is estimated by the model based on historical input data and is projected as part of the energy demand forecast. This projection can be adjusted through the use of process energy efficiency standards, where new buildings are required to meet a certain level of energy efficiency. Efficiency standards can be applied for specific building energy end-uses, such as air conditioning and heating, or to the building shell as a whole. A significant standard will produce energy savings, savings on fuel expenditures, lower GHG emissions, and an increase in new building capital cost. Reductions in energy usage and emissions will grow over time compared to a reference case with no standard as new buildings are constructed and old structures are retired.

Information/Data Required

- Description of the end-uses covered by the program and implementation years.

- Description of the standard as a rate of improvement from existing structures.

Net Zero Buildings

Description: Incorporate Net Zero homes and commercial/institutional facilities (universities, hospitals, municipal buildings etc.). A Net Zero building produces as much heat and electricity as it consumes on an annual basis.

Modeling Methodology: This can be achieved through a combination of measures that reduce household energy consumption and use an on-site renewable energy system, namely photovoltaic and/or solar thermal.

Information/Data Required: The information needed in order to incorporate a net zero program into the model include the following:

- Description of one or more designs for Net Zero buildings
- Process efficiency (energy service requirements) for Net Zero buildings
- Device efficiencies and capital costs for appliance in Net Zero buildings
- Capital cost of Net Zero buildings
- Capital costs and production of solar units for Net Zero buildings
- Expected fuel choices for Net Zero buildings (for example geothermal heating)

Appendix 1. List of Existing Policy Files in ENERGY 2020

The following is a list of policy files created for the 2016 reference case. These policy files can be used as a template for designing new policies.

- KPIA-Biofuels-Fed.txp - Federal biofuels programs (DMFrac)
- KPIA-Biofuels-Prov.txp - Provincial biofuels program (DMFrac)
- Com_BldgStdPolicy.txp - Commercial building codes
- Res_BldgStdPolicy.txp - Residential building codes
- B2016ComEq.txp - Commercial equipment standards
- B2016ResEq.txp - Residential equipment standards
- Ind_DeviceEff.txp – Industrial equipment standards
- HDV.txp - Transportation equipment standards
- TransElectric_Parameters.txp - Transportation electric vehicles
- TransElectric_AEO.txp - Transportation electric vehicles
- LDV2.txp - Transportation equipment standards
- VolPT.txp - Transportation equipment standards
- LCFS_BC.txp – Transportation alternative fuels
- ZEV_Prov.txp – Transportation alternative fuels
- ElectricMarketShare_NL.txp – Newfoundland and Labrador electrification policy (MMSM0)
- Biomass_NT.txp – Northwest Territories alternative fuels
- UnitAddCap_AB_CS.txp – Alberta Climate Strategy – new electric capacity
- Electric_Renew_NS.txp – Nova Scotia – renewable electricity
- CAC_TranStandards.txt – CAC emissions transportation standards
- CAC_CurrentPolicies.txt - CAC emissions standards
- CAC_VOC_Reduction.txt – VOC emission reductions
- CAC_TranMarine.txt – CAC emission marine transportation standards
- CAC_GasProcessing.txt – CAC emissions natural gas processing standards
- ParasiticLoss.txt – CAC emissions policy
- CAC_OffRoad.txp – CAC emissions policy
- CAC_ElecGen_AB_NoCASA.txp – CAC emissions policy for electric generation
- CAC_CleanAir_QC.txp – CAC emissions policy
- CAC_ElecGen_NS.txp – CAC emissions policy
- CAC_ProvRecipReg.txp – CAC emissions policy
- CAC_MSAPR.txp – CAC emissions policy
- DSM_NS.txt – Nova Scotia electricity efficiency policy
- GHGNonEnergyPolicy.txp – GHG emissions policy
- CT_New_SGER_AB_CS.txp – Alberta SGER Cap-and-Trade policy
- GHG_Tax_AB_CS.txp – Alberta GHG tax
- BCCarbonTax.txp – BC Carbon tax

- Electric_Offsets_BC.txp – BC Carbon offsets policy
- Electric_EPS_Coal.txp – Performance standard for electric coal generation
- ElectricCoalRetire_AB_CS.txp – Alberta coal retirement policy
- BoundaryDamCCS.txp – Saskatchewan coal CCS policy
- EPS_NS_GHGLimit.txp - Nova Scotia electric performance standard
- EPS_NS_HydroPurchases.txp - Nova Scotia hydroelectric purchases
- CASA_Coal_No_BLIER.txp – Alberta CASA for coal electric generation units
- Ref16CaliforniaPolicies.bat – California policy batch file
- WCI_Market.txp – WCI policy
- WCI_PriceP3.txp – WCI prices

Appendix 2. Cap-and-Trade Model Structures

ENERGY 2020 simulates all aspects that may be specified in a cap-and-trade system design. The structures that are able to be specified include:

- Emissions coverage criteria;
- Allocated allowances;
- Offsets;
- Allowance reserves;
- Banking and borrowing allowances;
- Allowance revenues; and
- Macroeconomic feedback.

Emissions Coverage: Emissions coverage identifies the geographic areas, economic sectors, and emissions included in the cap-and trade system. Through the use of model switches, ENERGY 2020 is designed to assign any set of areas (state, province, or territory), economic sectors, fuels, and pollutants to be included or excluded as part of a cap-and-trade system. The coverages are specified with a single variable which ranges between 0 (not covered) and 1.0 (100% covered). Values in between are often used to simulate systems which cover only facilities which exceed a certain level of emissions (for example facilities which emit more than 25,000 tonnes). These values can change over time as more sectors, areas or pollutants are incorporated into the cap-and-trade system.

Allocated Allowances: Allocated allowances are determined based on the emissions goal - the number of emission allowances is equal to the emission goal. These allowances are either allocated to participants or sold and traded in the market. Generally, some of the allowances are allocated freely to participants (gratis allowances) to reduce the economic impact of the program on the participants. Allowances can be allocated in many different ways including historical, forecast, and intensity based. The allocated allowance formulas may contain any number of factors including the age of the participants (new or old facility), the type of fuel being burned (special allowance for renewable fuels or waste fuels), or the type of operations (industrial generation of electricity). The allocated allowances are often reduced over time, so initially 80% of allowances may be allocated, but by 2025 only 15% are allocated freely, with the remainder being purchased at auction in the market.

Offsets: Sectors that often are not included in the cap-and-trade systems, such as agriculture and forestry are available for offsets. Offsets are intended to provide flexibility (and thus lower costs) in meeting the GHG goals, and their availability and price are defined in the cap-and-trade simulation. The offsets in ENERGY 2020 generally are simulated with an offset curve.

This curve has the GHG allowance price ($/tonne) as an input, while the output is the level of GHG reductions (tonne/year). Offsets, however, can have a more complicated simulation. The landfill gas offset results in the construction of electric generating capacity which burns landfill gas, methane, to produce electricity. Any excess methane, not used in electric generation, is flared. In both cases, the landfill gas, methane, is burned to reduce methane but increase CO2. See *Appendix 3. Offsets and Reductions Curves* for a description of the specific offset and other reduction curves defined in the model.

Allowance Reserves: Allowance reserves are a pool of allowances controlled by the regulatory authority that are released into the market to attempt to moderate prices. ENERGY 2020 adds allowances to the market when the price thresholds are reached. These extra allowances will mitigate the upward pressure on prices and result in a lower price to meet goals.

Banking and Borrowing Allowances: In order to provide flexibility (and thus reduce the financial burden) participants may be allowed to bank and borrow allowances. Banking consists of storing allocated or purchased allowances. Participants may bank allowances when prices are low or during periods when they are easily able to reduce emissions. ENERGY 2020 uses banking and borrowing when the GHG allowance price iteration involves an entire price series (a price for every year of the analysis period). When the model is run with a single price series, some years meet the goal some years exceed the goal, and some years fall short of the goal. The model assigns banking and borrowing to carry excess or shortfalls across years and thereby determine if the emissions meet the overall, multi-year goals of the system.

Allowance Revenues: Any allowances which the regulatory authority sells in an auction will generate revenue. The regulatory authority must decide what to do with this revenue. Options include rebates to the participants, tax reductions, lowering national debt, direct reduction of GHG, investments in energy efficiency, investments in GHG reducing technologies, or any other purpose deemed beneficial. ENERGY 2020 computes these revenues then passes them to the macroeconomic model, if available, or the other ENERGY 2020 sectors. The macroeconomic impact of recycling is dependent on the detail of the linked macroeconomic model.

Macroeconomic Feedback: The cap-and-trade system will have an impact on the economic growth, employment, and personal income of the area being regulated. These impacts will come from the requirement to purchase permits, the investments in new energy and emission reduction technologies, the increases in energy prices, and the method of utilization of the allowance revenues. ENERGY 2020 passes the cost impacts to the macroeconomic model which processes the impact on the economy.

Appendix 3. Offsets and Reductions Curves

Several mechanisms are in place to simulate the energy suppliers and consumers taking specific measures designed to directly mitigate emissions in response to price signals, such as increased prices due to carbon taxes or cap-and-trade systems.

The types of emissions-reducing mechanisms in place consist of offsets and reduction curves, implementing generic energy efficiency improvements, and improving work practices in the oil and gas industry. Electric utilities additionally will respond to increased emissions prices and/or targets by switching to lower-emitting fuel sources of generation, such as natural gas and renewables.

Offsets and Reduction Curves

Given an increased carbon price, three mechanisms are in place to reduce emissions based on reduction cost curves: 1) offset reductions from agriculture, forestry, and waste; 2) carbon capture and storage sequestering (CCS); and 3) improvements to industrial processes.

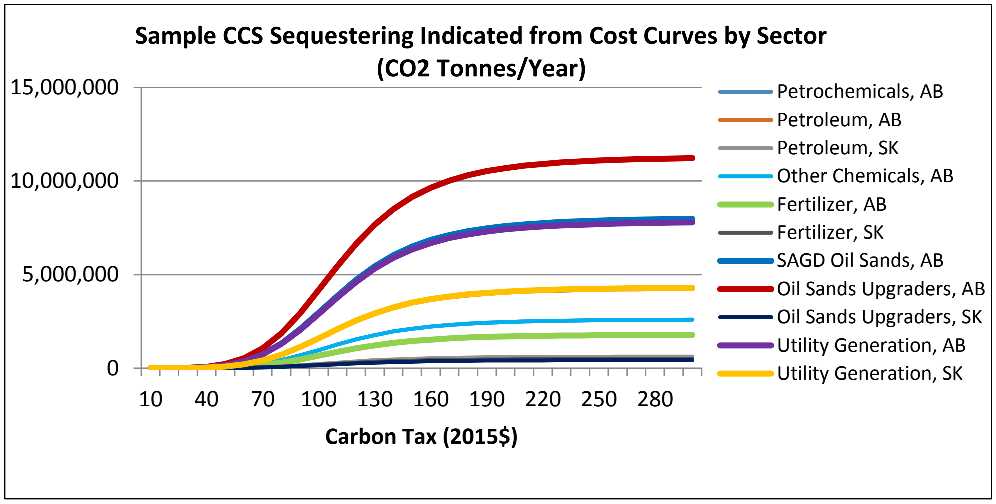
Offsets from Agriculture, Forestry, and Waste

There are currently seven types of offsets represented in ENERGY 2020. Each of the offsets is mapped to an economic category (ECC) in ENERGY 2020 and to a Pollutant. The offset mapping is listed below.

Offset		ECC		Pollutant
Landfill Gas Capture Solid Waste (LFG)	→	Solid Waste	→	CH4
Anaerobic Wastewater Treatment (WWT)	→	Wastewater	→	CH4
Aerobic Composting Solid Waste (AC)	→	Solid Waste	→	CH4
Nitrous Oxide Agriculture (NERA)	→	Crop production	→	N2O
Anaerobic Decomposition Agriculture (AD)	→	Animal production	→	CH4
Wood Biomass Agriculture (WB)	→	Crop production	→	CH4
Forestry	→	Forestry	→	CO2

Carbon capture and storage (CCS) sequestering

The amount of carbon capture and storage sequestering implemented is determined based on a carbon cost curve whose parameters are model inputs. CCS is represented in the Chemical, Oil Sands, and Electric Utility sectors within Alberta and Saskatchewan. An exogenous amount of sequestering also could be input to the model to indicate government developed CCS. The exogenous level of sequestering serves as the minimum amount of sequestering developed. A sample of the reduction cost curves represented in the model by type of gas and industry is shown in the figure below. Curve parameters are input through the policy file named *GHG_CCSCurves.txp* and stored in the 2020Model subdirectory.



Improvements to Industrial Processes: Industrial processes emission non-CO2 reduction cost curves are represented in the model. The figure below illustrates the fraction of emissions reduced at various levels of carbon taxes by economic sector.

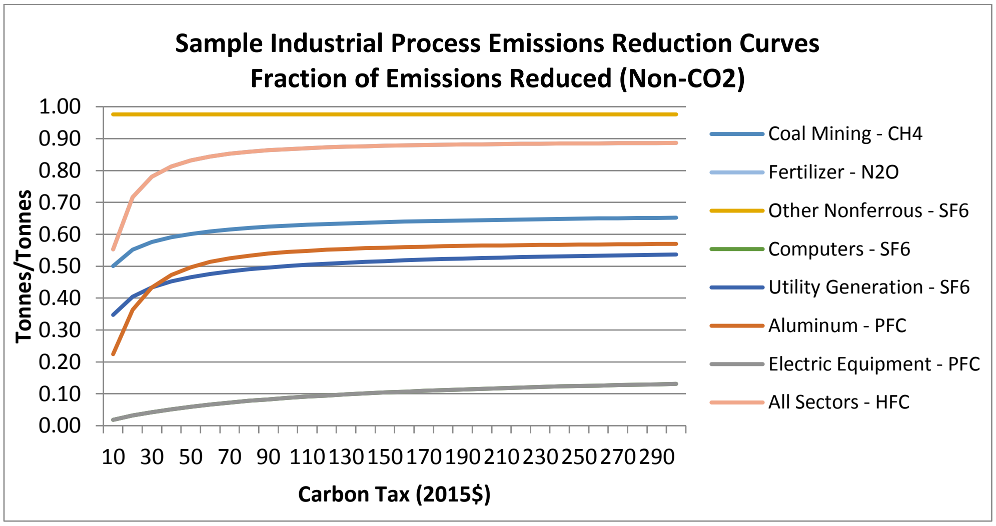


Table 8 identifies which pollutants are reduced by the emissions-reduction curves initiated by carbon prices. These curves are able to be set as active or non-active with the use of a model switch.

Table 8. Industries and Pollutants Impacted by Offsets and Reduction Cost Curves

	Industrial Sector	Industrial Processes	CCS	Agriculture, Forestry, Waste Offsets
1	Food & Tobacco	HFC	-	-
2	Textiles	HFC	-	-
3	Apparel	HFC	-	-
4	Lumber	HFC	-	-
5	Furniture	HFC	-	-
6	Pulp and Paper Mills	HFC	-	-
7	Converted Paper	HFC	-	-
8	Printing	HFC	-	-
9	Petrochemicals	HFC	CO2	-
10	Industrial Gas	HFC	-	-
11	Other Chemicals	HFC	CO2	-
12	Fertilizer	N2O, HFC	CO2	-
13	Petroleum Products	HFC	CO2	-
14	Rubber	HFC	-	-
15	Leather	HFC	-	-
16	Cement	HFC	-	-
17	Glass	HFC	-	-
18	Lime & Gypsum	HFC	-	-
19	Other Non-Metallic	HFC	-	-
20	Iron & Steel	HFC	-	-
21	Aluminum	PFC, HFC	-	-
22	Other Nonferrous Metal	SF6, HFC	-	-
23	Fabricated Metals	HFC	-	-
24	Machines	HFC	-	-
25	Computers	SF6, HFC	-	-
26	Electric Equipment	PFC, HFC	-	-
27	Transport Equipment	HFC	-	-
28	Other Manufacturing	HFC	-	-
29	Iron Ore Mining	HFC	-	-
30	Other Metal Mining	HFC	-	-
31	Non-Metal Mining	HFC	-	-
32	Light Oil Mining	HFC	-	-
33	Heavy Oil Mining	HFC	-	-
34	Frontier Oil Mining	HFC	-	-
35	Primary Oil Sands	HFC	-	-
36	SAGD Oil Sands	HFC	CO2	-
37	CSS Oil Sands	HFC	-	-
38	Oil Sands Mining	HFC	-	-
39	Oil Sands Upgraders	HFC	CO2	-
40	Sweet Gas production	HFC	-	-
41	Sweet Gas Processing	HFC	-	-
42	Sour Gas production	HFC	-	-
43	Sour Gas Processing	HFC	-	-
44	LNG production	HFC	-	-
45	Coal Mining	CH4, HFC	-	-
46	Construction	HFC	-	-

	Industrial Sector	Industrial Processes	CCS	Agriculture, Forestry, Waste Offsets
47	Forestry	HFC	-	CO2
48	On Farm Fuel Use	HFC	-	-
49	Crop production	HFC	-	N2O, CH4
50	Animal production	HFC	-	CH4
51	Utility Generation	SF6, HFC	CO2	-
52	Solid Waste	-	-	CH4
53	Waste Water	-	-	CH4

Generic Energy Efficiency Improvements

Code is in place which allows the industrial sectors to activate improvements to device and process efficiency curves. Additionally, generic device and process efficiency improvements are introduced to the model across the residential, commercial, and industrial sectors. The level of improvements is exogenously set.

Oil and Gas Industry Work Practices

Emission-reduction measures within the oil and gas industry (“work practices”) are incorporated into the model based on increases to carbon prices and include reductions from the following five areas:

- Venting emissions reductions
- Flaring emission reductions of CO2 from Reduced Emission Completion (REC) programs which capture gas from hydraulic fracturing
- Sequestering of formation CO2 - natural gas processing industry sequestering of formation CO2.
- Fugitive emission reductions from pneumatic device improvements
- Fugitive emission reductions from Leak Detection and Repair (LDAR) programs
- Other fugitive emission reductions CH4 – sets a minimum level based on an overall 45% target

A summary of the industries and pollutants impacted by the oil and gas work practices is listed in Table 9.

Table 9. Pollutants Reduced by Oil and Gas Industry Work Practices

ENERGY 2020 Sectors Impacted by Oil and Gas Industry Work Practices						
Industrial Sector	**Venting**	**RECs Flaring**	**Formation CO2 Sequestering**	**Pneumatic Devices Fugitives**	**LDAR Fugitives**	**Other Fugitives**
Light Oil Mining	CH4 (+CO2, VOC)			CH4		CH4
Heavy Oil Mining	CH4 (+CO2, VOC)			CH4		CH4
Frontier Oil Mining				CH4		CH4
Primary Oil Sands	CH4 (+CO2, VOC)					CH4
SAGD Oil Sands						CH4
CSS Oil Sands						CH4
Oil Sands Mining						CH4
Oil Sands Upgraders						CH4
Sweet Gas production		CO2			CO2, CH4, VOC	CH4
Sweet Gas Processing			CO2	CH4		CH4
Sour Gas production		CO2			CO2, CH4, VOC	CH4
Sour Gas Processing			CO2			CH4